HEWLETT PACKARD

HP 8451A Diode Array Spectrophotometer Operator's Manual

HP 8451A

Diode Array Spectrophotometer

OPERATOR'S MANUAL

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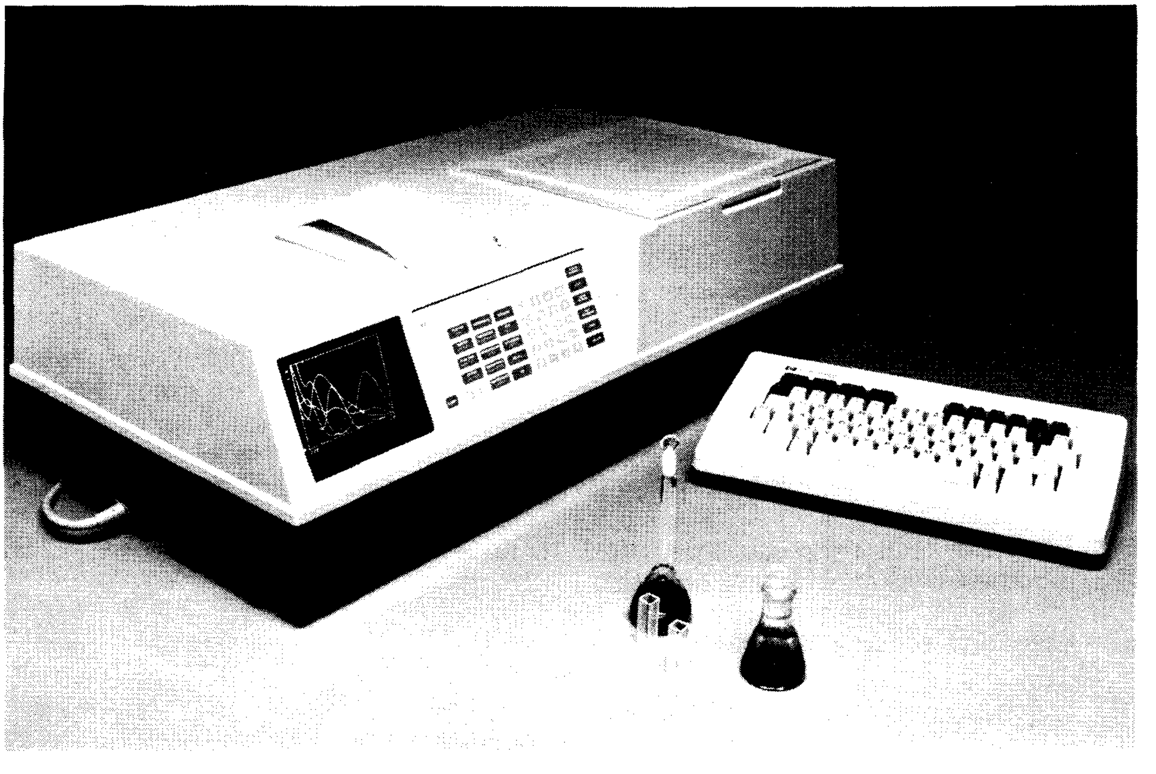
Section 1

GENERAL INFORMATION

INTRODUCTION

The HP 8451 Diode Array Spectrophotometer Operator's Manual is organized to enable the user to do the following:

- o Become familiar with the instrument and its options and accessories (Sections 1 and 2).
- o Unpack and install the unit (Section 3).
- o Operate the instrument using the built-in functional keyboard (Sections 4 and 5).
- o Use quantitation routines (Section 6).
- o Operate plotters, printers, disc drives, and other accessories which can be used with the spectrophotometer (Section 7).
- o Use BASIC programming commands to expand the instrument's capabilities (Section 8).
- o Perform routine maintenance procedures and use the built-in diagnostics (Section 9).



INSTRUMENT DESCRIPTION

The HP 8451 Diode Array Spectrophotometer is a single beam, microprocessor-controlled, UV-visible spectrophotometer which operates at high speed. Absorbance spectra over the full 190 to 820 nm wavelength range can be obtained in 0.1 second with a 0.7 second repetition rate. Values at up to 25 wavelengths can be obtained every 0.1 second.

The HP 8451 includes the operating system of the HP 85A Personal Computer including a built-in CRT and printer/plotter. The built-in functional keyboard allows easy entry of measurement parameters and data processing instructions. An alphanumeric keyboard accessory provides the extended capability and versatility of BASIC programming.

Important features of the HP 8451 include:

1. Single beam elliptical optics and a holographic grating designed for high throughput and sensitivity.
2. Diode array detector consisting of 328 photodiodes.
3. User-oriented built-in functional keyboard.
4. Optional alphanumeric keyboard accessory allowing BASIC programming.
5. Built-in CRT display.
6. Built-in printer/plotter.
7. Processor aided measurements yielding direct answers in absorbance, transmittance, or other user-defined function.
8. Calculation of up to seventh derivative with Savitsky-Golay smoothing.
9. Four concentration calculation methods for quantitation of a single component (optional).
10. Multicomponent analysis allowing quantitation of mixtures containing up to 12 components (available as an accessory).
11. Eight I/O ports for plug-in ROM and RAM memory, and interfaces, allowing communication with the alphanumeric keyboard, external plotters, printers, disc drives, computers, autosamplers, and other peripherals.
12. Cell temperature control and stirring accessories.
13. Program and data storage: 16K RAM standard, additional 16K or 128K modules available as accessories.
14. User and service diagnostic routines.

SPECIFICATIONS

Operating specifications for the HP 8451 are listed in Table 1-1. These specifications are the performance standards against which the instrument is tested. The environmental specifications are shown in Table 1-2. Specifications are subject to change without notice.

TABLE 1-1. PERFORMANCE SPECIFICATIONS

Item	Specification
Full Spectrum Scan Time	0.1 second
Data Repetitively Stored in Memory with BASIC program	
o Up to 25 wavelengths	0.1 second
o Full Spectrum Scan	0.7 second
Wavelength Range	190 to 820 nm
Wavelength Accuracy	+/- 2 nm
Wavelength Reproducibility (Typical under constant conditions)	+/- 0.05 nm
Spectral Bandwidth	2 nm
Full Dynamic Range, A/A 50%	0.0022 to 3.3 AU
Photometric Accuracy at 1 AU, 512 nm NBS 931 filters	+/- 0.005 AU
Baseline Flatness >200 nm 1-second reference followed by 1-second measurement	<0.0013 AU RMS at 1 second
Noise (at 500 nm, 60 one-second measurements at 0 AU)	<0.0002 AU RMS
Stability at 340 nm (Constant temperature; after instrument warm-up; at 0 AU)	
Measured over one hour (MEASURE 1,5,0,3600)	<0.0028 AU/hr
Measured over one minute (MEASURE 1,5,0,60)	<0.001 AU/min
Stray Light (measured with Hoya 056 Filter) at 220 nm	<0.05%
at 340 nm	<0.05%

TABLE 1-2. ENVIRONMENTAL SPECIFICATIONS

Item	Specification
Ambient Temperature	
Operating	0 to 40°C
Non-operating	-40 to 65°C
Maximum Rate of Change	10°C/hr
Humidity (25-40°C)	5 to 85%
Altitude	
Operating	4,600m
Non-operating	15,300m
Atmosphere	Non-condensing, non-corrosive
Line Voltage (selectable)	80-140 or 160-264 VAC
Frequency	47 to 440 Hz
Power	100 watts typical
Size	Width: 77.5 cm (30.5 in) Height: 24.3 cm (9.6 in) Depth: 43 cm (16.9 in)
Weight	26 kg (57 lbs)

ACCESSORIES

The plotters, disc drives, and related I/O instrumentation recommended for use with the HP 8451 are listed in Table 1-3. Other accessories are listed in Table 1-4.

TABLE 1-3. I/O INSTRUMENTATION

Model Number	Description
HP 7470A	Graphics Plotter - Two pen.
HP 9872C/T	XY Plotter - Eight pen.
HP 82905B	Impact Printer
HP 9121S/D	Flexible Disc Drive (3-1/2" discs)
HP 82901/2	Flexible Disc Drive (5-1/4" discs)
HP 9133/4/5	Winchester Disc Drive
HP 89006A	HP-IB Cable
HP 89059A	Peripherals Interface Kit

TABLE 1-4. ACCESSORIES

Model Number	Description
HP 89050A	Advanced Techniques Module
HP 82903A	16K Memory Module
HP 82909A	128K Memory Module
HP 82936A	ROM Drawer
HP 89057A	Alphanumeric Keyboard Kit
HP 89051A	Automated Sipper/Sampler System
HP 89052A	Peristaltic Pump
HP 89053A	Sipper/Sampler Interface
HP 89071A	Sipper/Sampler Tubing and Fitting Kit
HP 89054A	Thermostattable Cell Holder
HP 89055A	Cell Stirring Module

INSTRUMENT AND MANUAL IDENTIFICATION

The instrument serial number is located on the rear panel. Hewlett- Packard uses a two-section serial number consisting of a four-digit prefix and a five-digit suffix separated by a letter designating the country in which the instrument was manufactured (A = USA; G = West Germany; J = Japan; U = United Kingdom). The prefix is the same for all identical instruments and changes only when a major instrument change is made. The suffix, however, is assigned sequentially and is unique to each instrument.

If changes have been made in the instrument since this manual was printed, a yellow "Manual Change" supplement supplied with the manual defines these changes and explains how to adapt the manual to the newer instruments. The part number for the manual is also listed on the title page.

WARRANTY AND SERVICE AGREEMENTS

Hewlett-Packard guarantees its products to be free from defects in materials and workmanship, and to meet published specifications.

The customer is expected to maintain his equipment in the manner prescribed by Hewlett-Packard.

If, as determined by Hewlett-Packard Company, the instrument has not been misused, the warranty period ends 90 days after the date of shipment from the factory. For international orders, the warranty period ends 90 days after shipment from its final HP point. International warranty policies may vary to satisfy local requirements.

The following items are not covered by warranty:

1. Repairs due to use of paper not specified by HP for use in the 8451A.

2. Failures caused by improper interfacing to external devices.

3. Instrument damage due to abuse (dropping, solvent spills, hot surfaces, harmful environment, etc.)

4. Consumable items (e.g., lamps, paper, print head, dust filter) unless received defective.

A repair made under warranty does not extend the warranty period. A repair paid for by the customer is warranted for 90 days.

This warranty may be modified in accordance with the laws of your country. Please consult your local HP office for the period of the warranty, for shipping instructions and for the applicable wording of the local warranty.

In order to maintain full coverage under this warranty, the customer may perform the necessary maintenance. Alternatively, he may choose to enter into a Service Agreement with the Hewlett-Packard Service Organization for the performance of the work.

Details of service agreements together with prices applicable to your installation can be obtained from your local HP Sales and Service Representative.

HP 8451 SPECTROPHOTOMETER

The HP 8451 Diode Array Spectrophotometer is a single beam, microcomputer controlled general purpose spectrophotometer. Its high speed measurement system is capable of producing a spectrum over the full wavelength range (190 to 820 nm) in 0.1 second (at a 0.7-second repetition rate) or up to 20 single wavelengths every 0.1 second.

The standard HP 8451 is equipped with a built-in display screen (CRT) and printer/plotter.

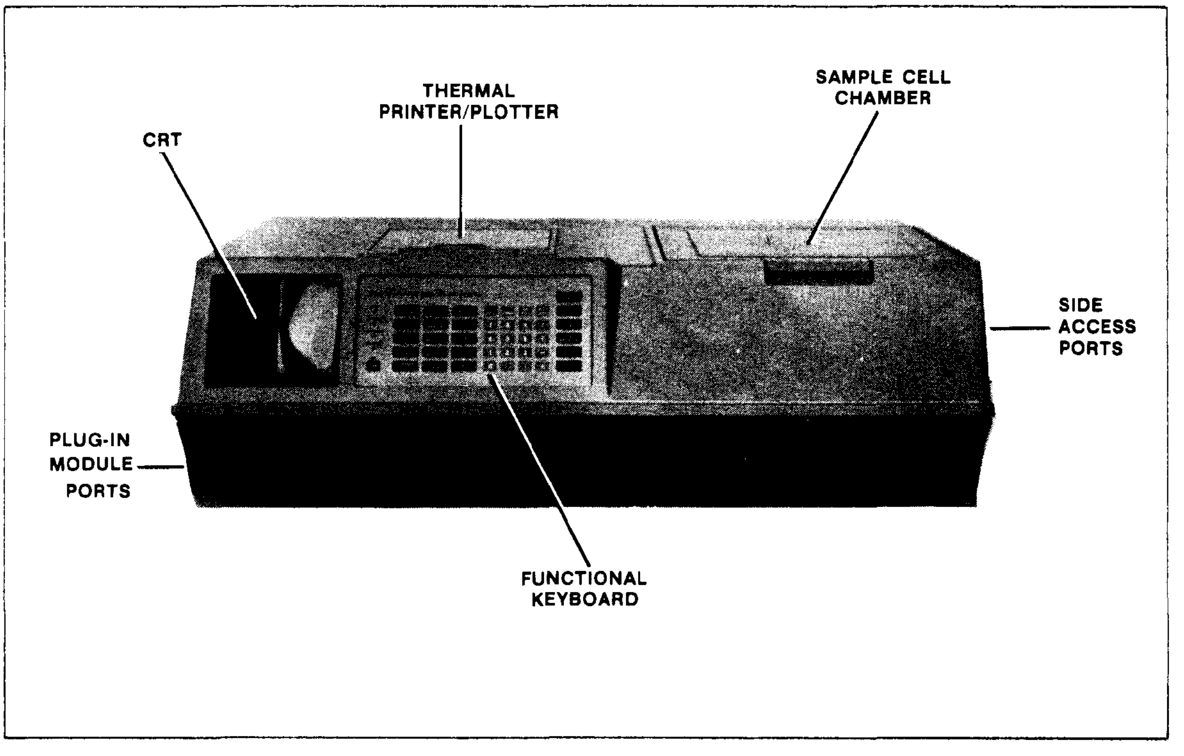


Figure 2-1. Standard HP 8451 System

The standard system spectrophotometer software plugs into one of eight I/O ports on the left side of the instrument. This module contains all operating software for performing spectrophotometer measurements and data processing operations. The remaining I/O ports are available for communication with plotters, printers, disc drives, autosamplers, additional software, memory modules, and alphanumeric keyboard.

OPTICAL SYSTEM

A schematic diagram of the optical system is shown in Figure 2-2. The radiation source is a deuterium lamp which emits radiation over the range 190 to 820 nm. The radiation results from a plasma discharge in low pressure deuterium gas contained in a quartz envelope. The emitted light is focused onto the sample cell by an ellipsoidal mirror, then reflected onto the monozone holographic grating by a second ellipsoidal mirror. The grating disperses the light onto a linear photodiode array. The photodiode array is a series of 328 individual light sensitive cells and control circuits etched on a semiconductor chip only 2 mm wide and 18 mm long. The full wavelength range of 190 to 820 nm utilizes 316 of these cells, the remainder allowing for alignment of the array during instrument wavelength calibration.

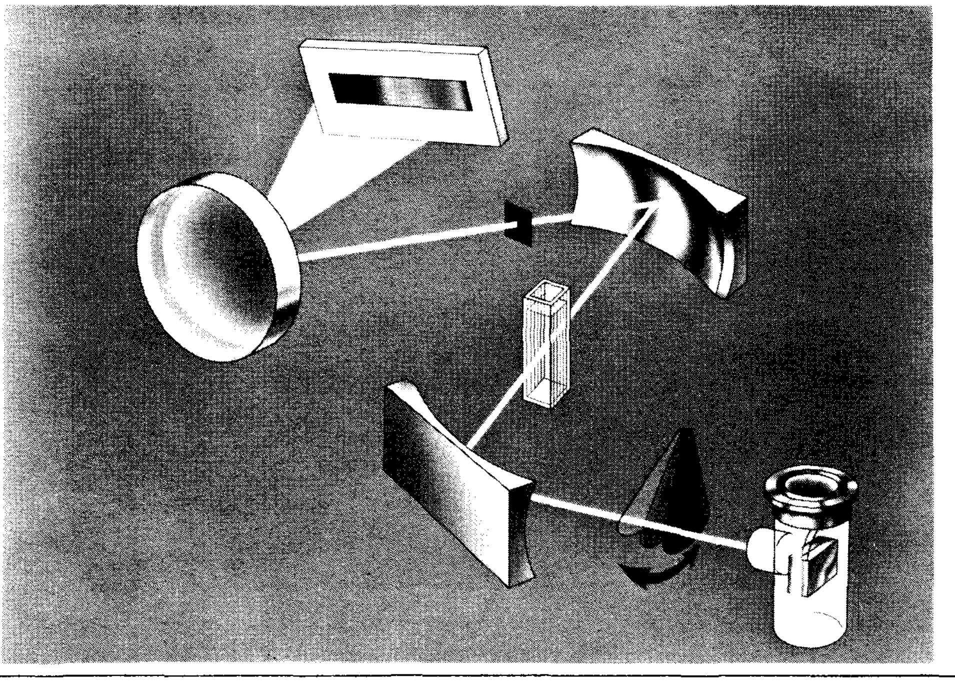


Figure 2-2. HP 8451 Optical System

A shutter, positioned between the lamp and the optical mirrors, cuts off radiation for measurement of dark current before and after each sample measurement.

The unique optical design utilizes only three reflecting surfaces and thereby obtains the high throughput required for high sensitivity measurements.

ELECTRONICS

A block diagram of the electronics is shown in Figure 2-3.

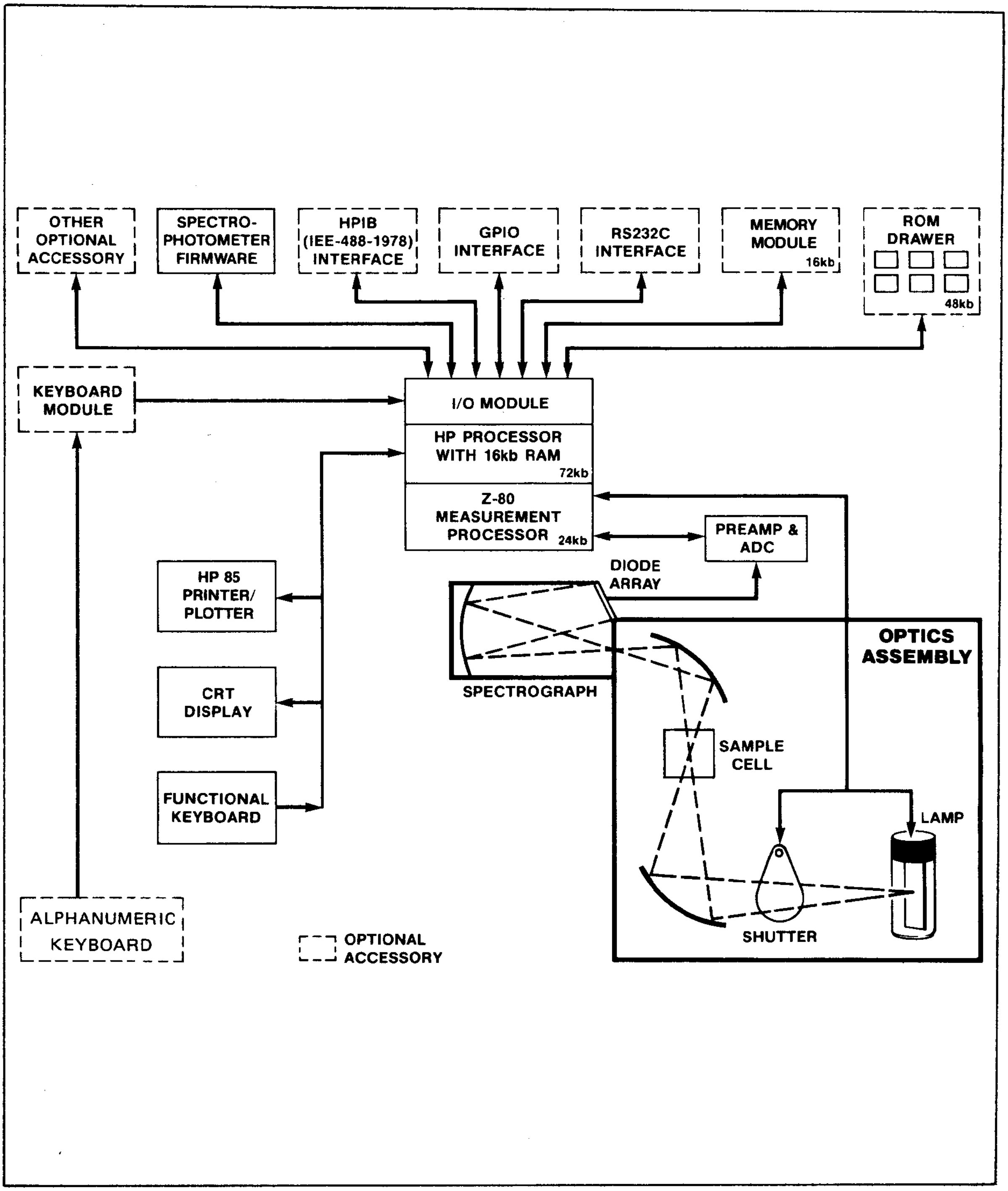


Figure 2-3. HP 8451 Electronics Block Diagram

Central to the operation of the HP 8451A are two 8-bit microcomputers, the Z-80 and the HP 85A. The Z-80 incorporates 24 kbytes (8k ROM and 16k RAM) while the HP 85A incorporates 72 kbytes (16k user RAM and 56k ROM). The 56 kbytes account for the operating personality of the HP 85A (32k) and HP 8451A (16k + 8k optional Advanced Techniques Module). With the optional 400 kbytes (16k plus 3 x 128k) of user RAM and the potential 48 kbytes of enhancement ROMs, the total HP 8451A capacity is 544 kbytes.

The Z-80 microcomputer controls the internal hardware (lamp, shutter, preamp and 14-bit ADC) and performs measurements, while the HP 85A microcomputer does data handling, controls peripherals and functions as interface between user and the basic instrument.

The HP 8451A has eight ports located on the left side of the instrument. One of the eight slots is configured for the alphanumeric keyboard module; however, there are no restrictions on the position of the modules used in the other seven, and they are self-configuring (i.e., the plug-in modules are automatically identified by the operating system with no user involvement except to plug them in).

The printer/plotter is a thermal printer that uses a moving print head (5 x 7 dot matrix) to print on a special heat-sensitive paper. It prints quickly and quietly at 6.7 lines per inch at about two lines per second. The thermal paper is 4.2" wide and prints 32 characters per line. Alpha output is bi-directional and graphics output is uni-directional.

INTRODUCTION

This section contains information and instructions for installing the HP 8451 Diode Array Spectrophotometer and its associated accessories. Repackaging instructions are also included.

INSTALLATION REQUIREMENTS

Power

The HP 8451 can operate using a line voltage between 80 and 140 volts AC or between 160 and 264 volts AC. The appropriate range is selected by a voltage selector switch on the back panel of the instrument. Instruments are shipped with the selector switch set at "230". The line frequency may be 47 to 440 Hz, single phase. Typical power consumption is 100 watts (VA).

Power Cable

Power cords supplied by HP have polarities matched to the power-input socket on the instrument, as shown below:

L = Line or Active Conductor (also called "live" or "hot")
N = Neutral or Identified Conductor
E = Earth ground

Use only the HP 8451 power cable specified by Hewlett-Packard for your area. If it is necessary to replace the power cord, the replacement must have the same polarity as the original. Otherwise a safety hazard from electrical shock may exist. In addition, the equipment could be extensively damaged.

Power cords with different plugs are available for the HP 8451. The part number, along with an illustration, of each cord is shown in Figure 3-1. Each plug has a ground connector. The cord packaged with the instrument depends on where the instrument was delivered. If your equipment has the wrong power cord for your area, please contact your local Hewlett-Packard Office for information on how to obtain the proper cord.

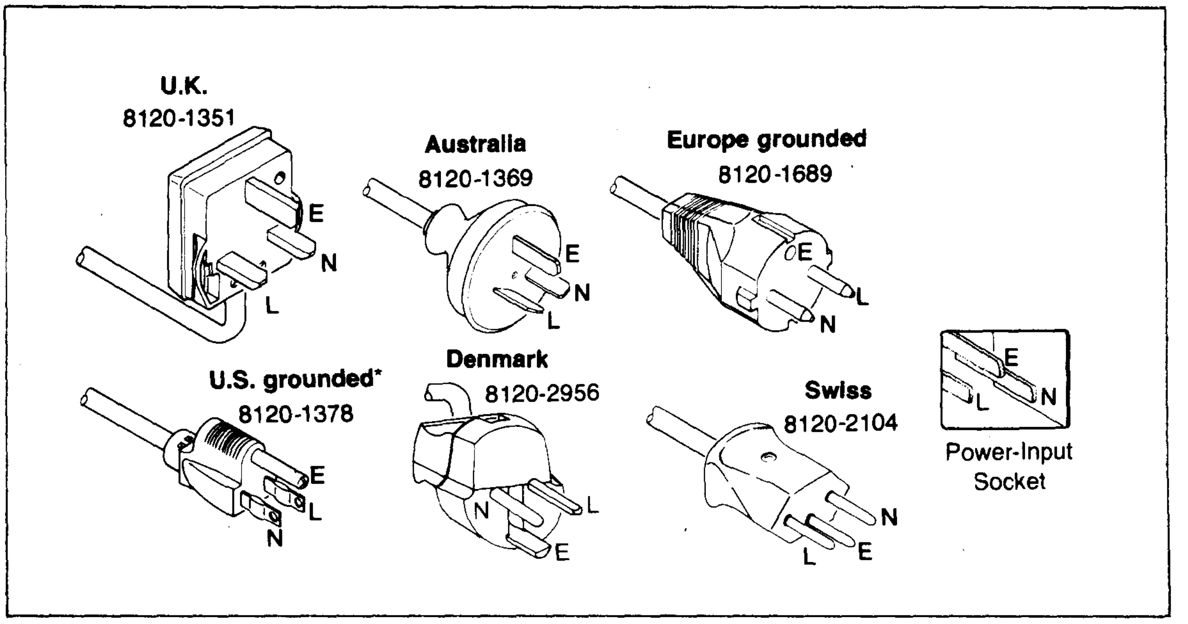


Figure 3-1. Power Cords

Grounding

To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recommends that all equipment not double insulated be properly grounded. The HP 8451 is equipped with a three-conductor power cable which, when connected to an appropriate power receptacle, grounds the instrument. To preserve this protection feature, do not operate the instrument from a power outlet which has no ground connection.

Fuse

The receptacle for the main fuse for the HP 8451 is located in the power module on the rear panel. The fuse cap and proper fuse are packaged with the instrument, together with the power cord appropriate to the shipping destination. For replacement, order the following fuses:

2110-0055 (4a) for use on 80-140 VAC
2110-0002 (2a) for use on 160-264 VAC

ENVIRONMENTAL REQUIREMENTS

Operating and Storage Temperatures

The HP 8451 operates within specifications at ambient temperatures of 0 to 40 degrees C. The rate of temperature change under any conditions must be less than 10 degrees C per hour.

The instrument may be shipped or stored where the ambient temperature is between -40 and 55 degrees C provided the rate of change is less than 10 degrees C per hour. The instrument should not be stored or shipped where temperature fluctuations cause condensation within the instrument.

Relative Humidity

The instrument may be operated in environments with relative humidity in the range 5% to 80% (non-condensing) providing the dry bulb temperature is less than 40 degrees C. The instrument must be protected from temperature conditions which cause condensation within the instrument.

Altitude

The instrument may be operated at altitudes up to 4600 meters and stored at altitudes from 300 meters below sea level to 15,200 meters above.

UNPACKING

Upon receipt, inspect the shipping carton for any signs of damage. If the container or cushioning material is damaged, it should be saved until the contents have been checked for completeness and the instrument has been mechanically and electrically checked. If the contents are incomplete (see Table 3-1) or if there is mechanical damage, notify the nearest Hewlett-Packard office. If the shipping container is damaged or the cushioning material shows signs of stress, notify the carrier as well as HP and save the shipping material for the carrier's inspection.

TABLE 3-1. EQUIPMENT SUPPLIED

Description	HP Part Number
Power Cord (USA)*	8120-1378
Fuse (for 80-140 VAC)	2110-0055 [4A 250V]
(for 160-264 VAC)	2110-0002 [2A 250V]
Sample Holder Assembly (installed)	08451-60104
Spectrophotometer Software	08451-60103
Operator's Manual	08451-90001
Paper (2 rolls)	82931A

*See Figure 3-1 for other power cables.

SET-UP INSTRUCTIONS

Workspace Selection

A conventional laboratory bench having an unobstructed surface 51 cm (20 in) deep by 93 cm (366 in) wide is adequate for the HP 8451. The bench should be capable of supporting 26 kg (57 lb). A space of at least 8 cm (3 in) should be allowed around the instrument for ventilating air flow.

Situate the HP 8451 in the workplace selected allowing access to the rear panel for connection of power cable and to the left side for installation of plug-in modules.

CAUTION

> Be sure that the table underneath the instrument is free of loose papers etc., as they can be pulled up against the air input filter and prevent proper cooling of the instrument.

Rear Panel Controls

Before applying power to the HP 8451. Check that the power switch on the rear panel is in the off position (0). See Figure 3-2.

Ensure that the line voltage selector on the rear panel is set for the voltage range in your area. To alter the setting, insert the tip of a small screwdriver into the slot on the switch and slide the switch to the required position (see Figure 3-3). Also ensure the proper fuse has been installed for the voltage selected (see page 3-3).

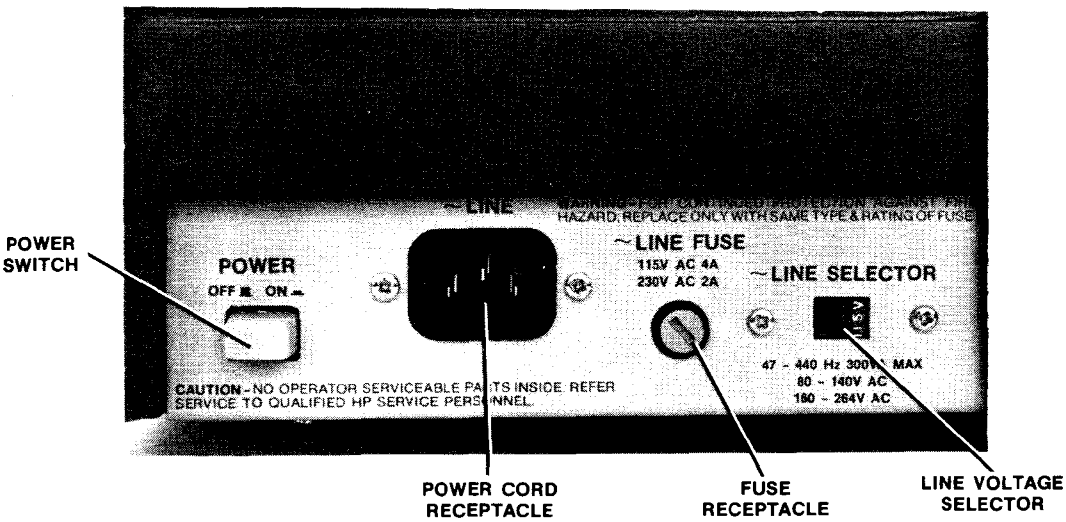


Figure 3-2. Rear Panel Controls

Disconnect the power cable before installing or replacing a fuse. Then follow these steps (Figure 3-3):

1. Turn the fuse cap counterclockwise with a screwdriver.

2. Place the new fuse in the fuse cap.

3. Insert fuse and cap into fuse receptacle and turn it clockwise until it locks in place (about 1/4 turn).

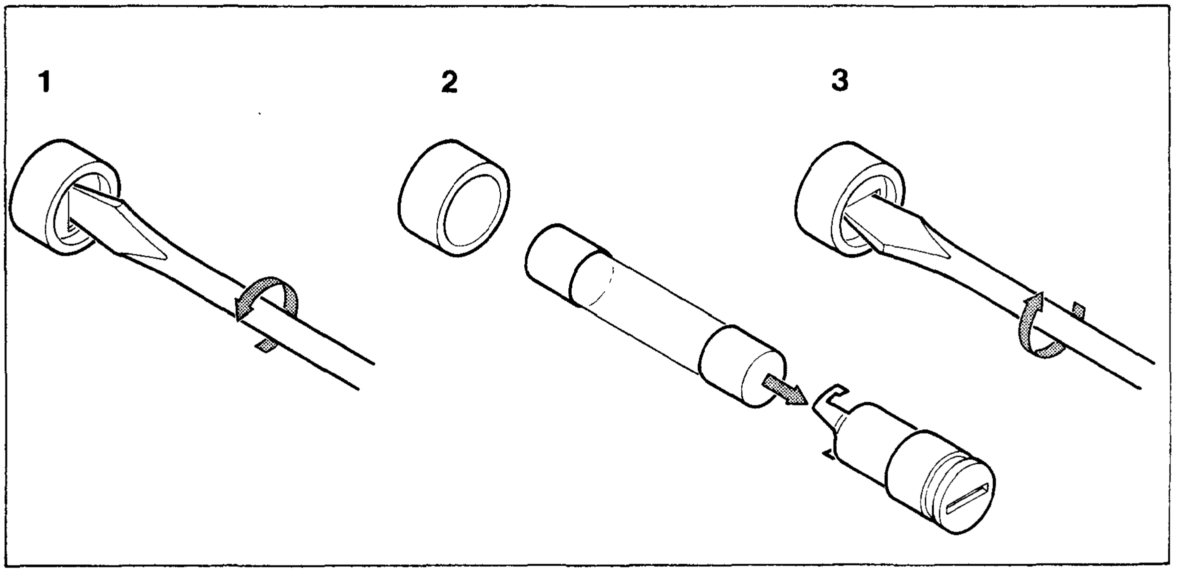


Figure 3-3. Fuse Replacement

HP 8451 INITIAL TURN ON

Regardless of the ultimate HP 8451 configuration, the basic spectrophotometer operation should be verified before any accessories are installed. After the proper line voltage range setting and fuse installation have been confirmed, the sample compartment should be cleared of any papers or shipping materials. The only object in the sample compartment should be the cell holder assembly and the sample holder baseplate. The path between the two optical windows in the cell compartment should be unobstructed.

The spectrophotometer software module (HP Part No. 08451-60103) which is shipped with every HP 8451 gives the spectrophotometer its "personality". This module contains 16K bytes of Read Only Memory which contain the firmware that enable the HP 8451 to operate as a spectrophotometer. Unless the spectrophotometer module is correctly installed by the user, the HP 8451 will not function as a spectrophotometer.

As shown in Figure 2-1, the space at the lower left side of the HP 8451 is allocated for plug-in modules. Of the eight ports for plug-in modules, the lower right (or forward) port is reserved specifically for the alphanumeric

keyboard. For operation, the spectrophotometer software module must be installed in one of the seven general purpose ports.

CAUTION

Before installing (or removing) the spectrophotometer software module, make sure the power to the instrument is turned off. Unless the power is turned off, internal electrical damage may result when a module is installed.

To install the spectrophotometer software module, first remove the plastic protective cover from one of the general purpose I/O ports (any port except the lower front port). Next, position the module with the label on top and insert the contact end into the port (see Figure 3-4).

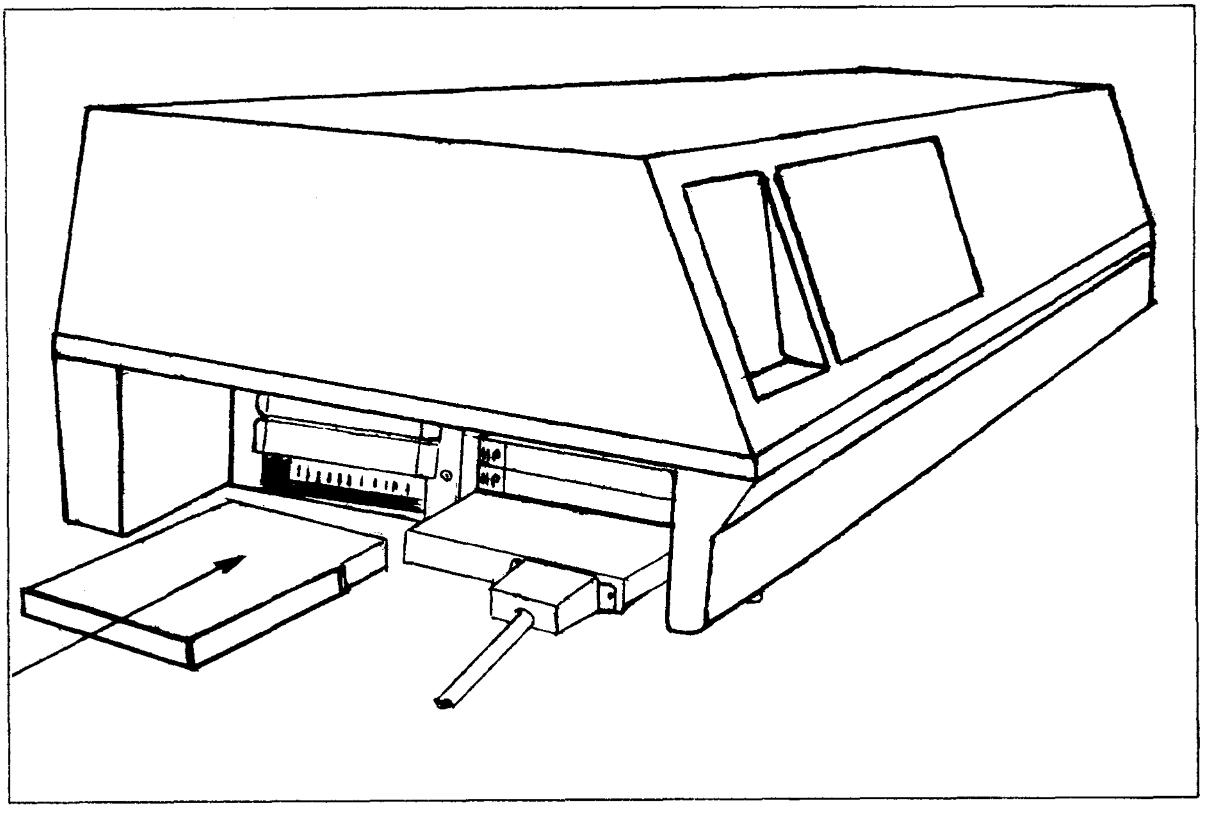


Figure 3-4. Installation of the Plug-In Modules

Slide the module in until its edges meet the sides of the port. A slight side-to-side motion will probably be necessary to fully seat the module in the port. The tracks are keyed to prevent the module from being installed upside down.

After the spectrophotometer software module has been properly installed, the line voltage range set, the correct fuse installed, and the sample compartment cleared, the HP 8451 power cable should be connected at the right rear of the instrument. The other end of the power cord should be plugged into the proper AC voltage source. Then turn on the power switch at the right rear of the instrument (shown in Figure 3-2).

After about 15-20 seconds, the instrument status report (Figure 3-5) should appear on the CRT. The POWER, MEASURING, and DIAGNOSTIC lights at the left side of the keyboard should light. At turn-on, system diagnostics are performed automatically. If any problems are detected, an error message is displayed on the screen. Consult Section 9, Diagnostics, and Appendix 1 for explanation of specific error messages.

```
MEASURE 1,0,0,0
LAMBDA 190 TO 820
Y-SCALE AUTO 0 TO 0
output PLOTTER 1
function ABSORBANCE
LAMP TURN-ON
bandwidth 2 nm
7856
```

Figure 3-5. Turn-On Status Report

After approximately 90 seconds, only the POWER and LAMP lights should remain on.

If the spectrophotometer software module is <u>not</u> properly installed (or not installed at all), instead of a status report the system will display "Error 23: Self Test" at turn-on. If this error message is displayed, turn off the instrument and (1) check that the module is inserted all the way into the port, or (2) move the module to another of the general purpose I/O ports. Turn on the instrument power and check for the status report, the absence of error messages, and after 90 seconds only the POWER and LAMP LEDs being lit.

If the HP 8451 turned on as just described, a preliminary spectral measurement should be made to ensure that the system is working properly. With the sample area clear, enter the following commands on the HP 8451 functional keyboard:

REFERENCE EXECUTE
MEASURE EXECUTE

After approximately ten seconds, a "baseline" spectrum will appear on the CRT (see Figure 3-6). This spectrum will be "noisy" for two reasons. First, the instrument has not had a sufficient warm-up period (normally 20 minutes is required). Second, the Y-scale is automatically adjusted so that the spectrum fills the CRT screen. If the magnitude of the Y-scale was increased, the baseline would appear flatter.

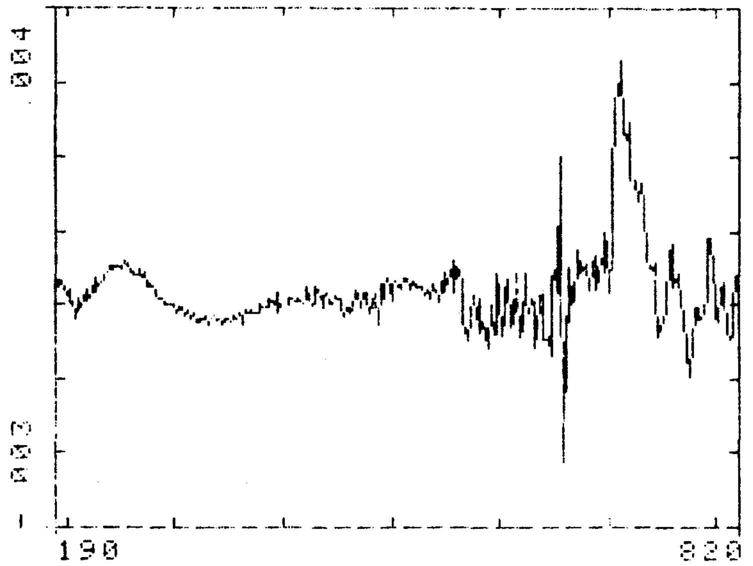


Figure 3-6. Baseline Spectrum During Warm-Up

If the status screen and spectrum are displayed, the HP 8451 is probably functioning correctly. If an error message is displayed, consult Section 9 and Appendix 1 to get further information on the cause and possible solution to the fault condition. If problems still remain, contact your HP representative.

After a status report has been generated and a baseline spectrum has been successfully measured, install the printer paper and HP 8451 accessories.

PAPER INSTALLATION

Because the printer in your HP 8451 is a thermal printer, it requires special heat-sensitive paper. You should use only the Hewlett-Packard thermal paper available in 400-foot long rolls from your nearest authorized HP dealer or HP sales and service center. The part number is 82931A.

Because of the special heat-sensitive requirements of the paper, impact printer paper will **not** work in the 8451A. Also, since different types of thermal paper vary in their sensitivities and abrasiveness, the use of thermal paper other than that available from Hewlett-Packard may result in poor quality and excessive print head wear.

CAUTION

Use only Hewlett-Packard paper in your HP 8451. Failure to do so may result in excessive print head wear.

The heat-sensitive paper used in your 8451 should be stored in a cool, dark place. Discoloration of paper may occur if it is exposed to direct sunlight for long periods of time, if storage temperatures rise above 65 C (149 F), if the paper is exposed to excessive humidity or to acetone, ammonia, alcohols, or other organic compounds, or if you attempt to erase anything on the paper. (Exposure to gasoline or oil fumes will not harm your HP 8451 paper supply.)

Printed paper from your HP 8451 will last 30 days or more without fading under fluorescent light, but to ensure the permanence of your records, you should store printed paper at room temperature in a dark place away from direct sunlight, heat, or fumes from organic compounds.

Loading Printer Paper

Printer paper is loaded by using the following procedure (see Figure 3-7). To perform the following steps, the spectrophotometer must be correctly installed and the instrument must be switched ON.

1. Open the hinged paper access cover by gently lifting the front edge of the cover up and back until it stops.

2. Remove the empty paper core with the roll guide tabs from the paper well by pulling gently until the roll guide tabs are released from their sockets. Discard the old paper core but save the roll guide tabs at either end of the paper core. Remove any paper remaining from the previous roll by pressing the "Paper Adv" key until the remaining paper stops moving. Then lift the paper out of the printer mechanism.

3. Discard the first 1-1/2 turns of the new roll to insure that no glue, tape, or other foreign matter is on the paper. Make sure that the leading edge of the paper is straight and cleanly cut or folded. A crooked or jagged leading edge will not engage properly in the paper advance rollers.

4. Insert the cylindrical ends of the roll guide tabs into the core of the paper roll. Using both hands to hold the roll guide tabs in place, rest the paper roll on the paper well. Make sure that leading edge of the paper is positioned to unroll forward from the bottom. Align the roll guide tabs with the roll guides in the paper well.

5. Pull approximately six inches of paper out of the roll and evenly insert the leading edge over and into the grey throat of the paper feed. Continue manually feeding the paper until it halts. Press and hold the paper advance key until the leading edge of the paper passes the top edge of the clear plastic tear bar. Close the hinged access cover, keeping the paper clear. See Figure 3-7.

To verify the printer operation, the CRT display may be copied to the printer by pressing the COPY key on the HP 8451 functional keyboard. If the printer head moves and the paper advances but nothing is printed on the paper, make sure that the HP thermal printer paper is correctly installed (see Figure 3-7). If the printer will not function, contact your HP representative.

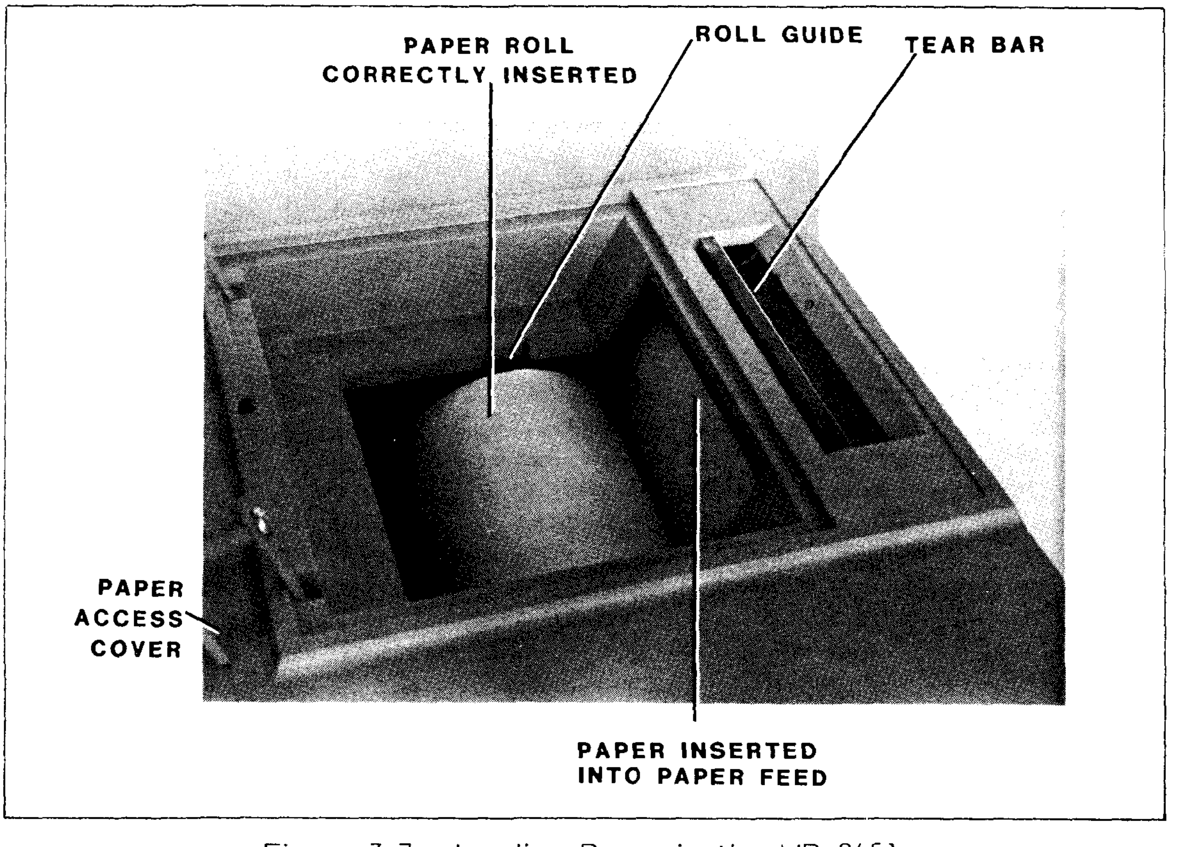


Figure 3-7. Loading Paper in the HP 8451.

INTERFACING THE HP 8451 WITH PERIPHERAL DEVICES

Overview

The analytical capabilities of the HP 8451 Spectrophotometer can be expanded with the use of selected peripherals devices. The more frequently used peripheral devices are: external plotters and printers, mass storage devices such as disc drives, and hardware (e.g., pumps, valves, autosamplers, etc.). For efficient communication to occur between the HP 8451 and specific peripheral devices, an interface is positioned between the HP 8451 and the peripheral device. An interface is the hardware link that provides compatability between the HP 8451 and the peripheral device in four major areas. These are:

Mechanical Compatibility	-	All plugs and connections must fit together.
Electrical Compatibility	-	Current and voltage levels must be matched.
Data Compatibility	-	Messages may have to be translated before the devices can communicate.
Timing Compatibility	-	The communication speed must be matched. Proper timing is controlled by a timing mechanism called <u>handshaking</u>.

The peripheral device chosen will usually determine which interface is needed. The four common interfaces used with the HP 8451 are:

HP-IB Hewlett-Packard Interface Bus. This is the HP implementation of the IEEE-488-1978 standard. This interface has an 8-bit parallel bus structure which permits bi-directional communication between instruments. The HP 8451 can control up to 14 HP-IB compatible devices from the one HP-IB port.

RS-232 This serial interface enables the HP 8451 Spectrophotometer to communicate with a variety of devices that are configured for serial communication. These devices include serial printers and other computers.

GP-IO General Purpose Input/Output. The general purpose parallel interface is a byte (8-bit) or word (16-bit) oriented interface. This interface is commonly used with special instrumentation such as pumps, valves and autosampler.

Keyboard Interface A special interface that is used to connect the HP 8451 to the HP 98155 keyboard.

Connecting Devices on the HP-IB

To connect one or more HP-IB compatible devices to the HP 8451, follow the arrangement shown in Figure 3-8. The total length of cable permitted with one bus interface must be less than or equal to two meters times the number of devices connected together (the interface is counted as one device). The total length of the cable must not exceed 20 meters. There are no restrictions as to how many cables may be connected together. However, it is recommended that no more than three or four piggy-back connectors be stacked together on one device. Excessive connectors on one device could exert enough force on the connector to cause mechanical damage.

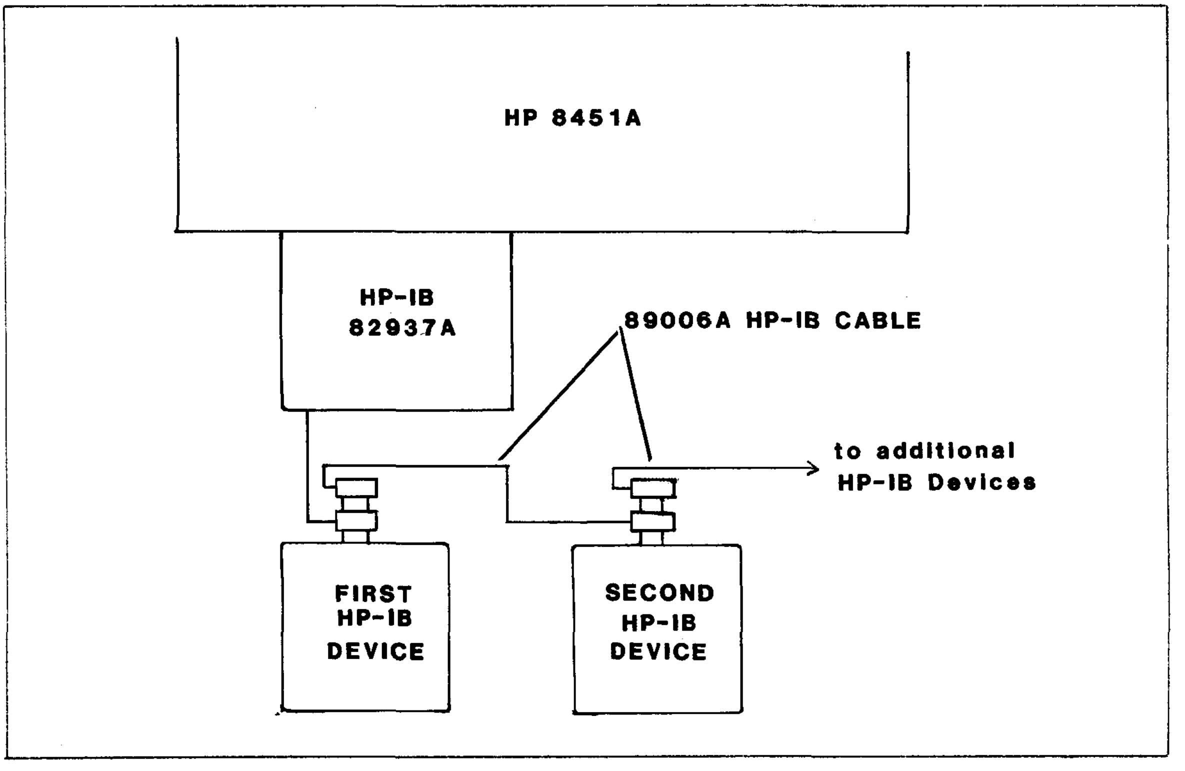


Figure 3-8. Arrangement of Peripherals for an HP-IB Interface

For RS-232 devices, an arrangement similar to that shown in Figure 3-8 should be used.

The GPIO Interface is available as a universal interface (HP 82940A) or a special purpose interface for a sipper/sampler system (HP 89053A). In both cases, the interface acts as the hardware link between the HP 8451 and the respective special instrumentation.

To operate the peripherals that may be connected to the HP 8451 Interfaces, various enhancement ROMs are required. These ROMs contain firmware to increase the instrument's programming capability. The ROMs most frequently used are listed in Table 3-2. Up to six different ROMs can be installed in a single ROM Drawer (HP 82936A).

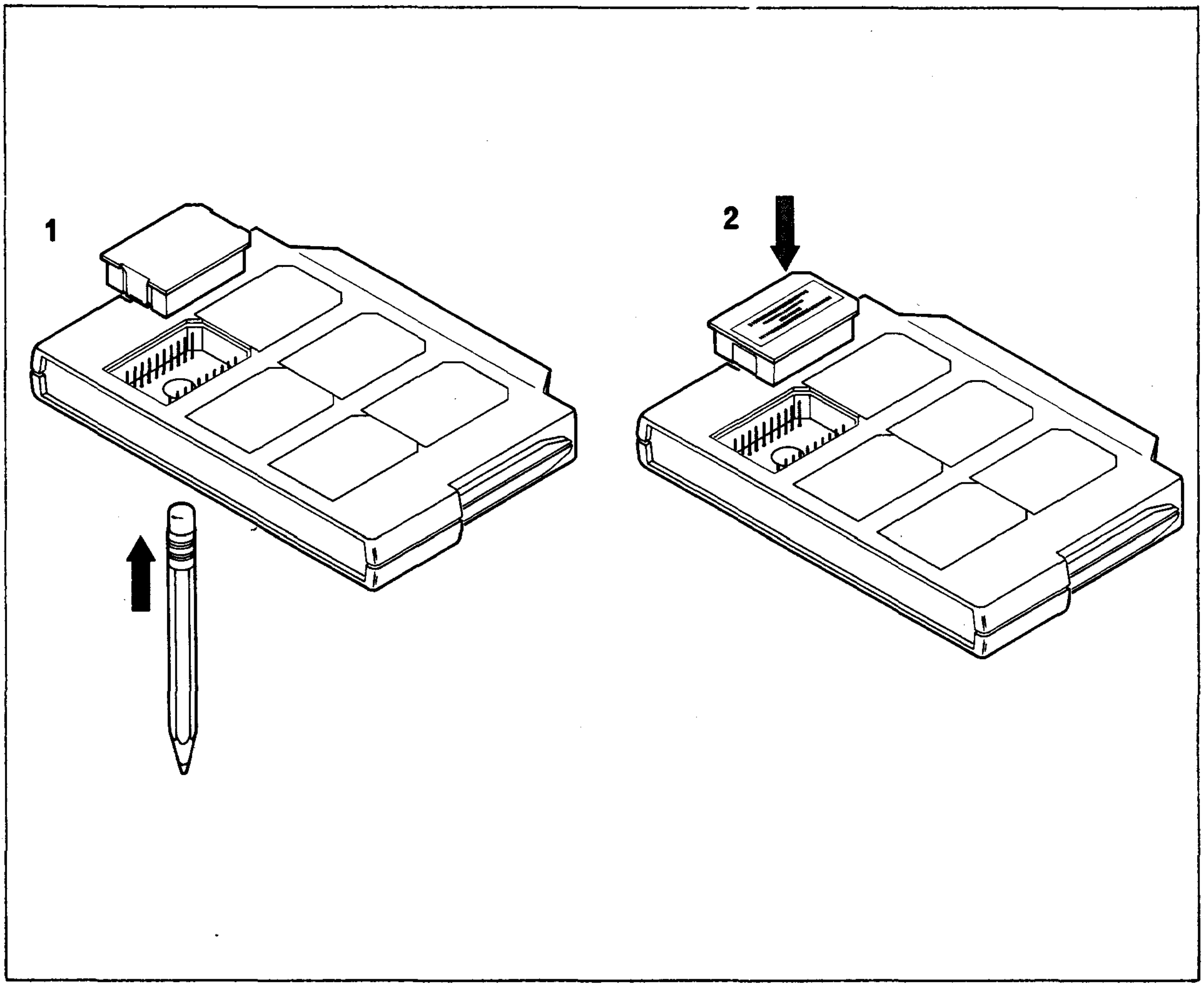


Figure 3-9. Insertion of ROM into ROM Drawer

Figure 3-9 shows how to install a ROM into the ROM Drawer. First remove the plastic cover from an empty ROM socket by pushing up through the circular hole on the underside of the ROM Drawer with the eraser end of a pencil. Inside each plug-in socket in the ROM Drawer are two rows of spring finger connectors. These connectors correspond to the two rows of holes on the underside of the ROM. The ROM and its socket are keyed so that the ROM can only be inserted one way. Align the ROM over the socket and press lightly into the ROM Drawer until it is flush with the top of the Drawer. The ROMs may be inserted in any order and into any of the ROM Drawer sockets. The procedures for installing the loaded ROM Drawer in the HP 8451 is given in the following section.

TABLE 3-2. OPTIONAL ENCHANCEMENT ROMS

ROM Type	HP Part Number	Required for:
Mass Storage	00085-15001	Disc Drives
Plotter/Printer	00085-15002	Plotters or Printers
Input/Output	00085-15003	Certain I/O Programming commands
Matrix	00085-15004	Programming Statements for matrices
Advanced Programming	00085-15005	Additional Programming Capabilities
Assembler	00085-15007	Assembly Language Programming

Installation of Additional Plug-In Modules

Before continuing the installation procedure, the basic operation of the HP 8451 should have been confirmed. Be sure to check the following:

- o Unpacking the instrument
- o Placement of the instrument at the chosen work station
- o Setting the voltage range switch
- o Confirming the proper fuse installation
- o Installation of the spectrophotometer software module
- o Connection to AC source
- o Instrument turn-on
- o Spectral measurement
- o Paper installation/printer verification
- o Loading the ROM drawer

If the proper instrument performance has not been verified, do not continue the installation procedure. Attempt to solve any problems using information

supplied in this manual. If the instrument can not be made to work correctly, contact the local HP representative.

If the instrument is working satisfactorily, turn the instrument off and proceed with the installation of additional plug-in modules and peripherals.

WARNING

> To protect internal circuitry, turn off the instrument power when any modules are installed or removed from the HP 8451.

The spectrophotometer software module should already be installed into one of the seven general purpose I/O ports. If an alphanumeric keyboard is available, the keyboard interface module should be installed in the lower front port. The alphanumeric keyboard kit consists of a HP 98155 keyboard (includes a built-in two-meter cable and connector) and a HP 89057-60100 keyboard interface module. First, remove the plastic protective cover, then install the module using the procedure described for the installation of the spectrophotometer software module (also see Figure 3-4). After the keyboard interface module (HP 89057-60100) is in place, connect the alphanumeric keyboard (HP 98155A).

After the alphanumeric keyboard has been installed, it should be checked for proper operation. Turn on the HP 8451 and wait for the turn-on sequence to be completed (approximately 90 seconds). Then type in:

REFERENCE	then press the END LINE key
MEASURE	then press the END LINE key

The END LINE key on the alphanumeric keyboard is equivalent to the EXECUTE key on the HP 8451 functional keyboard. When the preceding commands have been executed, the CRT will display a "baseline" spectrum (see Figure 3-6).

If the CRT display is not affected by pressing keys on the alphanumeric keyboard, turn off the power to the HP 8451 and check to see that the keyboard interface module is fully seated in the keyboard port. Check the connection at the keyboard cable connector (25 pins) and the keyboard interface module. After this is complete, turn on the power to the HP 8451 and repeat the preceding keyboard test. If the alphanumeric keyboard will not work, contact the HP representative.

If the CAPS LOCK key is depressed on the alphanumeric keyboard, numerous keys on the HP 8451 functional keyboard will not function. The CAPS LOCK key should normally be in the up position. Further information on alphanumeric keyboard operation is given in Section 8, Basic Programming.

A list of optional plug-in modules is given in Table 3-3. With the exception of the alphanumeric keyboard module, these modules can be installed in any

of the general purpose I/O ports. The seven general purpose I/O ports are mechanically and electrically equivalent. They differ only in their processor interrupt priority. The HP 8451 uses a "daisy chain" (serial) priority interrupt scheme. The keyboard scanner and internal timers have the highest interrupt priorities. Next on the serial polling scheme are the seven general purpose I/O ports. These ports are polled in the order shown in Figure 3-10.

TABLE 3-3. OPTIONAL PLUG-IN MODULES

Module	HP Part Number
Alphanumeric Keyboard	89057A
Advanced Techniques Module	89050A
16K Memory Module	82903A
128K Memory Module	82909A
ROM Drawer	82936A
HPIB Interface	82937A
Sipper/Sampler Interface	89053A
Serial Interface	82939A
GPIO Interface	82940A

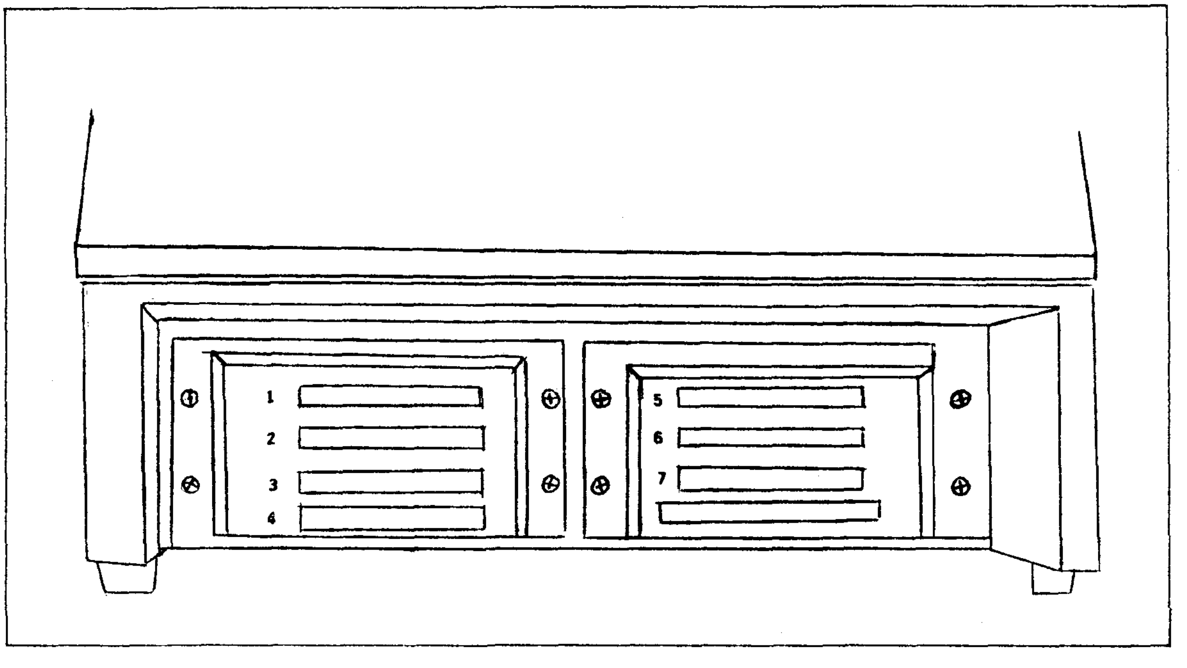


Figure 3-10. Polling Interrupt Order of the General Purpose I/O Ports

For a serial polling scheme, these plug-in modules that are capable of interrupting the processor should be placed in the ports with the highest interrupt priorities. Therefore, modules such as the HP-IB, serial and GP-IO interfaces should be located in the rear ports (#1, #2, #3, #4). Modules that contain only enhancement ROMs are not able to interrupt the processor. ROM modules should be placed in lower priority interrupt port (#5, #6, #7). In the same way the personality module was installed, additional modules are installed by first removing the plastic protective cover and then inserting the contact end of the module into the port. A slight side-to-side motion may be necessary to fully seat the port. The tracks are keyed to prevent the module from being inserted upside-down.

PERIPHERALS INSTALLATION

NOTE

> In order to avoid large circulating ground currents, all components of your system (HP 8451A, HP-IB peripherals, and accessories) should be plugged into the same branch circuit or plug strip.

HP 7470A XY Plotter

Power Requirements:

Line Voltage:	100/120/220/240 VAC (+5%, -10%)
Line Frequency:	48 to 66 Hz
Power Consumption:	25 watts maximum

Consult the HP 7470A Operator's Manual (07470-90002) for full details of specifications and operation. Information given here is limited to correct installation for use with the HP 8451. Figure 3-11 shows the rear panel connections of the HP 7470A.

Check that the plotter is configured to operate from the line voltage available. Line voltage selection is identified in the small recessed window on the rear panel, see Figure 3-11. The line voltage can be changed by qualified service personnel only. Line voltage selection procedures are described in the X-Y Plotter Service Manual (07470-90000).

Check that the correct fuse is installed. Ensure that the power cable is disconnected before installing or replacing a fuse. To install or replace a fuse, follow the procedure described in the HP 7470A Operator's Manual.

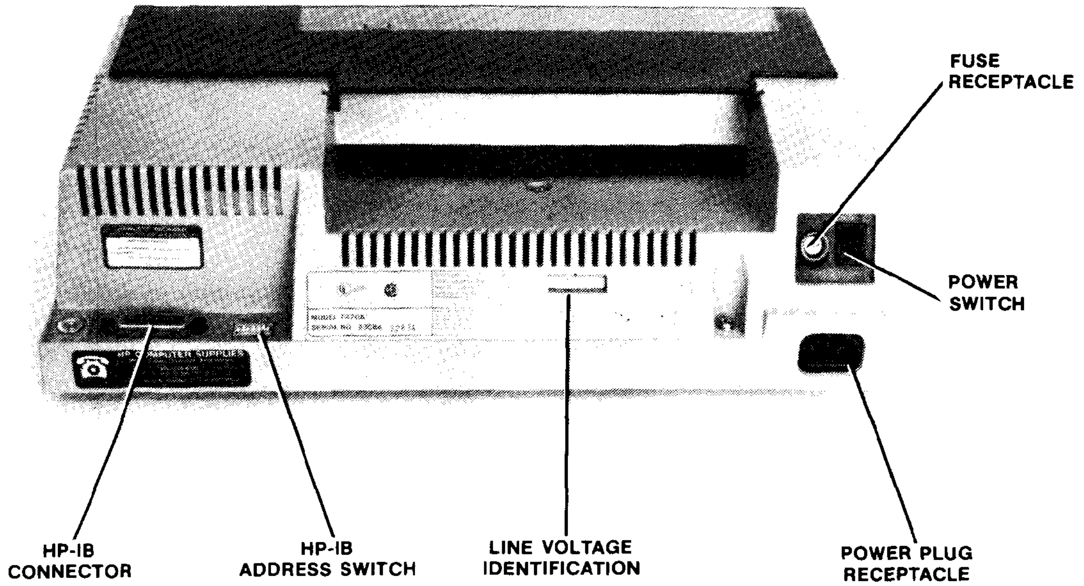


Figure 3-11. Rear Panel of HP 7470A Plotter

The device address switch (for location see Figure 3-11) is preset to 5 at the factory. See Figure 3-12. This is the correct setting for operation with the HP 8451A system and it need not be changed. Switch number 7 on the device address switch sets the plotter for the required paper size. Two settings are possible: US (8.5 in x 11 in ANSI A) or A4 (210 mm x 297 mm ISO A4). Switch number 6 is not used.

Ensure that the Plotter/Printer ROM is correctly installed in the HP 8451A. If the 7470A is the first, or only, HP-IB peripheral to be connected to the 8451A, connect the free end of the HP-IB cable to the HP-IB connector on the rear panel of the 7470A. Ensure that the cable is securely held by the connecting screws. If another HP-IB peripheral (e.g., disc drive) has been installed prior to the plotter, connect the plotter to this peripheral using a 89006A HP-IB Interconnect Cable.

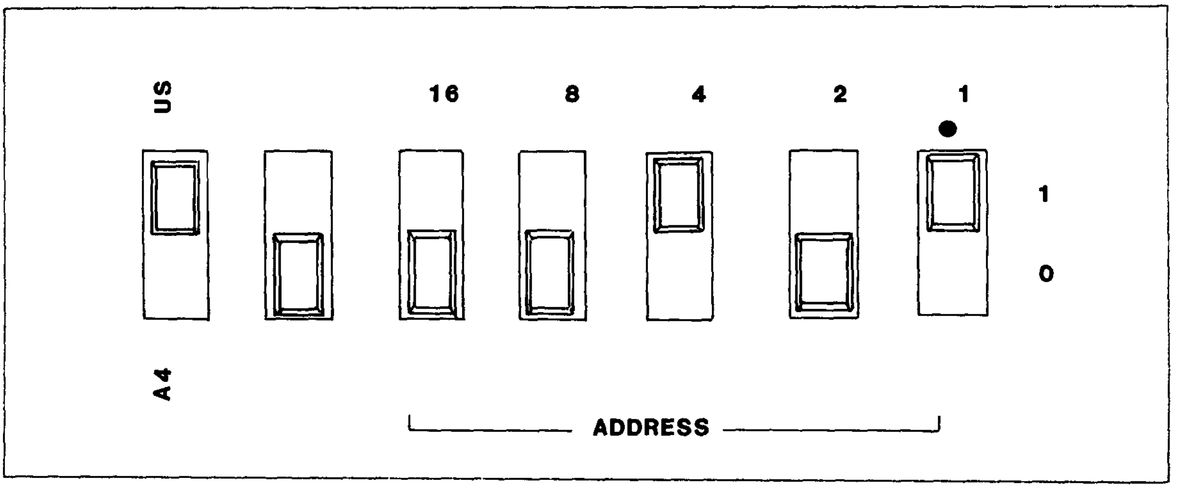


Figure 3-12. Correct HP 7470A Device Address Setting
(Set for US Paper Size)

The HP 7470A Self-Test should be performed to verify the proper operation of the plotter. The test is detailed in the HP 7470A Operator's Manual. After the pens and paper have been properly installed, this test is initiated by holding the **PEN UP** push button down while the power switch is turned from off to on. If the pens are picked up and an asterisk is printed on the paper, the plotter is functioning properly. If the plotter will not pass the self-test, the plotter is defective and service is required. For normal HP-IB operation, the plotter address is 705. Seven refers to the HP-IB select role, and five is the device address code.

Other Plotters

A variety of other HP plotters, such as the HP 7475A and 9872C/T, may be connected to the HP 8451 in a manner similar to that described for the HP 7470A. The device address should be set to 5. Further information, including the self-test procedure, should be obtained from the respective plotter Operator's Manual. If the plotter will not pass the self-test, the plotter is defective and service is required. For normal HP-IB operation, the plotter address is 705. Seven is the HP-IB select code, and five is the device address code. Further information on plotter operation is given in Sections 5 and 7.

HP 9121D Disc Drive

Power Requirements:

Line voltage: 86-125 / 195-250 VAC
Line Frequency: 50-60 Hz
Power Consumption: 80 watts RMS (102 voltamps)

Consult the HP 9121D Operator's Manual (HP 09121-90000) for full details of specifications and operation. Information given here is limited to correct installation for use with the HP 8451. Figure 3-13 shows the rear panel connections of the 9121D.

Check that the disc drive is configured to operate from the line voltage available, and that the proper fuse has been installed. The line voltage selector switch and the fuse receptacle are located on the rear panel (see Figure 3-13).

The device address switch (for location, see Figure 3-13) is preset to 0 at the factory, see Figure 3-14. This is the correct setting for operation with the HP 8451A system, and it need not be changed. Switches number 0, 1, and 2 should be in the "DOWN" position, and the switch labeled "TEST" should be in the "UP" position.

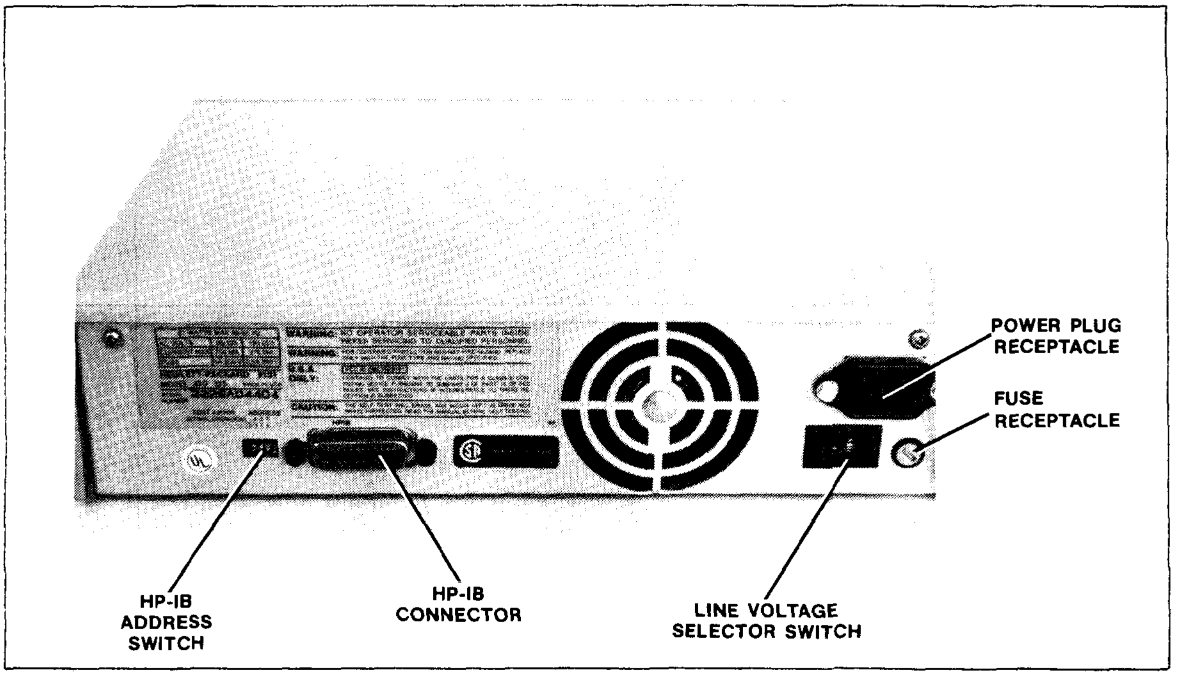


Figure 3-13. HP 9121D Rear Panel Connections

Ensure that the Mass Storage ROM is correctly installed in the 8451A (see Figure 3-9). If the HP 9121D is the first, or only, HP-IB peripheral to be connected to the 8451A. and then connect the free end of the HP-IB cable to the HP-IB connector on the rear panel of the 9121D. Ensure that the cable is securely held by the connecting screws. If another HP-IB peripheral (e.g., plotter) has been installed prior to the disc drive, connect the disc drive to this peripheral using a 89006A HP-IB Interconnect Cable.

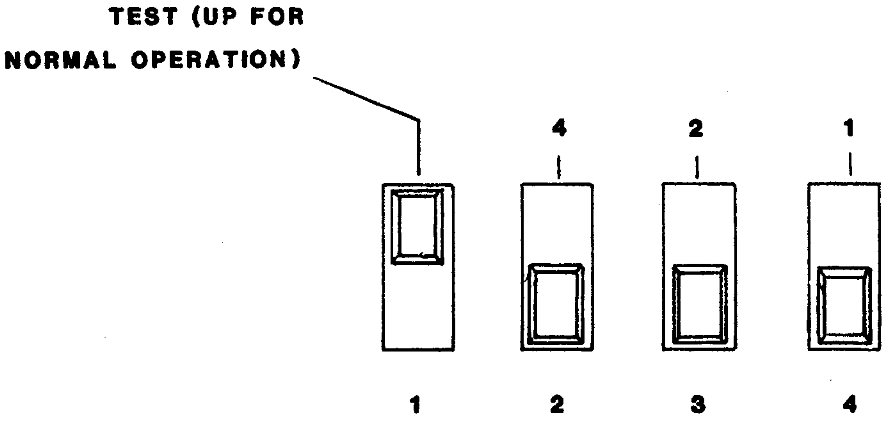


Figure 3-14. Correct HP 9121D Device Address Setting

Refer to the HP 9121D Operator's Manual for a procedure that details various self-tests that can be performed to verify the disc drive performance. If the disc drive self-test can not be completed successfully, the disc drive is defective and service is required. The disc drive can be addressed by ":D700" for the left drive and ":D701" for the right drive. The seven is the HP-IB select code. The middle numeral, zero, is the disc drive address code. The final numeral refers to the left (0) or right (1) drive.

Other Disc Drives

A variety of other HP disc drives, such as the 82900 5-1/4" flexible disc series and the 9130 Winchester disc series, may be connected to the 8451 in a manner similar to the 9121D as described above. The device address code for the 82900 series should be set to 0 (labeled as "on"). The device address code for the fixed disc on a 9130 series drive should also be set to 0. When using a 9130 series drive containing a fixed disc and a flexible disc (such as the 9133A or 9135A), set the address of the fixed disc to 0 and the address of the flexible disc to 1. The fixed disc is then addressed as ":D700" and the flexible disc addressed as ":D710".

A drive self-test should be performed to ensure that the drive is operating properly. The material can be obtained from the disc drive Operator's Manual. If a disc drive will not pass the self-test, the drive is defective and service is required. The drive should pass the self-test before it is connected to the HP 8451.

Other HP-IB Devices

If other HP-IB devices are connected on the HP-IB, they should have a unique device address code. If two HP-IB peripherals have the same device address

code, neither device will function properly. If possible a self-test should be performed on any device before it is added to the HP 8451 system.

Troubleshooting HP-IB Devices

If an HP-IB peripheral passes its self test and has a unique address, the HP 8451 should be checked for error messages that result from attempted operation with a suspected defective device. Error messages and explanations are listed in Appendix 1. If none of the HP-IB peripherals can communicate with the HP 8451, it is possible that the HP-IB interface is defective or that the internal HP-IB address has been set incorrectly. To check the address setting, turn off the HP 8451 and all HP-IB peripherals. Remove the HP-IB module and remove the six screws shown in Figure 3-15. The correct swtich setting is shown in Figure 3-15. If the correct address is set, check each switch to ensure it is fully enabled. Reassemble the HP-IB interface module, reinstall it, turn on the peripherals and then the instrument and check for proper operation. If the system will not operate, contact the HP representative.

START UP PROCEDURE

After completing the installation of plug-in modules and other accessories, connect the power cable of the HP 8451 and of its peripherals. Next turn on all peripherals. Then turn on the power switch at the right rear of the instrument.

After about 15-20 seconds the system start up message will appear on the CRT. System diagnostics are then performed automatically. If any problems are detected an error message is displayed on the screen. Consult Section 9, Maintenance, and Appendix 1 for an explanation of error messages.

After approximately 90 seconds, when the POWER and LAMP lights at the left of the keyboard remain on and all others are off, the instrument is ready to perform measurements. The turn-on status report (see Figure 3-5) will be on the CRT display.

Make a preliminary spectral measurement to verify the system operation. With the sample area clear, enter the following commands on the HP 8451 functional keyboard:

REFERENCE EXECUTE
MEASURE EXECUTE

After approximately 10 seconds, a "baseline" spectrum will appear on the CRT (see Figure 3-6). If this spectral measurement has been made, it is likely that the HP 8451 and all peripherals are operating correctly.

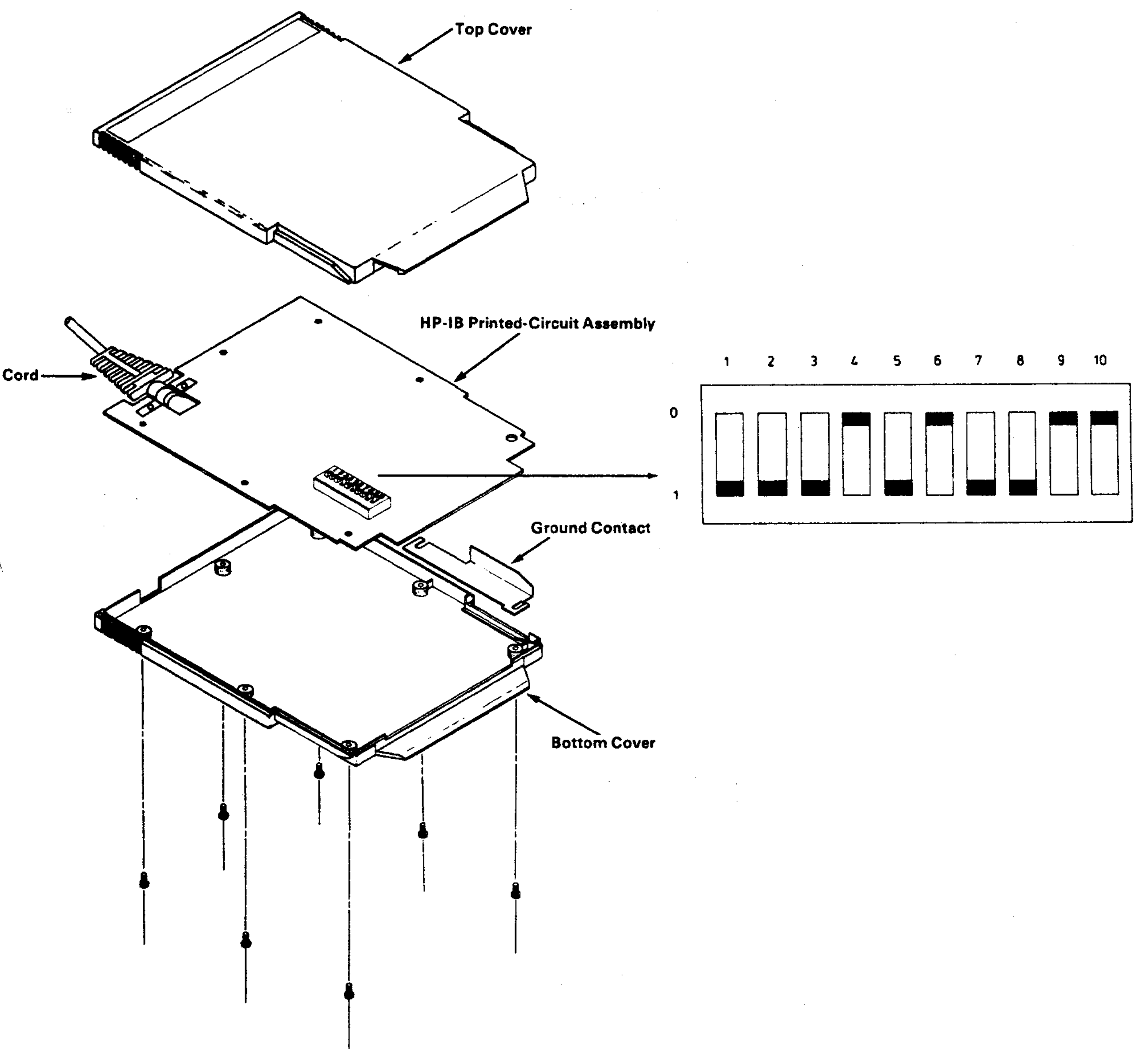


Figure 3-15. Dissassembly of HP-IB Module

If the preliminary spectral measurement can not be made, check the CRT display for error messages. If the problem can not be resolved, turn off the power to the HP 8451 and remove any plug-in module except the spectrophotometer software module. Turn on the HP 8451 again and check for the fault condition. Selectively remove modules (with the HP 8451 power off) until the faulty module can be isolated. If the faulty module is the ROM drawer, selectively remove enhancement ROMs until the defective ROM is located. If the problem can not be resolved, contact the HP representative.

Additional troubleshooting material is given in Section 9, Maintenance.

NOTE

Although measurements may be performed immediately, an approximate 20-minute warm up period is required to ensure operation within performance specifications.

REPACKAGING FOR SHIPMENT

If the original container is available, place the instrument in the container with appropriate packing material and seal well with strong tape or metal bands. If the original container is not available, a new one may be ordered through your local Hewlett-Packard Office.

Choose a shipping method consistent with the environmental requirements described earlier (page 3-2).

If the instrument is to be returned to Hewlett-Packard for any reason, contact your local HP sales/service office. HP service personnel will provide shipping instructions, or handle the shipping for you. Attach a tag to the instrument including the following information:

1. Your company name
2. Address
3. Telephone number
4. Name of person to contact
5. Description of problem and desired service
6. HP 8451 Serial Number

When the instrument is returned to HP, all plug-in modules should be included with the shipment. In general, do not include the power cord or peripheral devices such as plotters, disc drives, or other special hardware.

SPECTROPHOTOMETER OPERATION

INTRODUCTION

This section describes operating techniques including sample preparation, start-up procedure, and entry of keyboard commands. A detailed discussion of command syntax, including limits for all parameters, is given in Section 5.

We recommend that the operator read through Section 4 once thoroughly, and then use Sections 4 and 5 for reference as necessary.

> **NOTE**
>
> If you wish to quickly check the correct usage of a particular command, refer to either the pull-out cards under the front right of the instrument or to the description of keyboard commands found in Section 5 of this manual.

SAMPLE PREPARATION

Solvents

A clean sample cell should be rinsed with the intended solvent at least three times (five times is recommended) before filling with the pure solvent that will be used in the measurement. Blotting with the cell inverted on a small stack of absorbent tissues will remove small residual amounts of solvent. This treatment will minimize any residual contamination from previous experiments.

Samples which contain colloidal dispersions, dust or other particulate matter should be filtered, centrifuged or allowed to settle. If not, the spectral information will be superimposed on the overall attenuation-of-transmittance spectrum due to scattering and/or reflection of light from the sample.

The choice of solvents is based mainly on the solvent's absorbance characteristics over the range of interest, its suitability as a solvent for the solute material, and experimental conditions. Table 4-1 lists common solvents and the lower limit of their useful wavelength range.

When using volatile solvents such as acetone or methylene chloride, make sure that the sample cell is stoppered since evaporation of a solvent may change solute concentration or cause "solution noise" due to index of refraction changes with convection effects and thus affect the accuracy of a measurement. Stirring and temperature control are also recommended with volatile solvents.

TABLE 4-1. LOWER LIMIT OF UV TRANSMISSION FOR SOME COMMON SOLVENTS

Approximate Lower Limits	Solvent
180-195 nm	Sulfuric acid (96%) Water Acetonitrile
200-210 nm	Cyclopentane n-Hexane Glycerol 2,2,4-Trimethylpentane Methanol
210-220 nm	n-Butyl alcohol Isopropyl alcohol Cyclohexane Ethyl ether
245-260 nm	Chloroform Ethyl acetate Methyl formate
265-275 nm	Carbon tetrachloride Dimethyl sulfoxide Dimethyl formamide Acetic acid
280-290 nm	Benzene Toluene m-Xylene
Above 300 nm	Pyridine Acetone Carbon disulfide

NOTE

Be sure to be aware of the fundamental safety precautions when using these compounds.

Sample Cells

Quartz face plates or quartz cells are required for use of the full 190 to 820 nm wavelength range. If operation will be restricted to the visible range of 350 to 820 nm, good quality glass cells may be used.

The faces of the cell should be wiped clean of any fingerprints or other contaminants. The oils in fingerprints are significant absorbers in the UV region and, if left on the surface, can cause erroneous results. However, once a "reference" measurement has been made, the faces of the cell should not be wiped again unless a new "reference" is measured. Always reinstall a cell with the cell number facing the same direction to minimize problems with cell non-uniformity. When possible, the sample cell should be left clamped in position throughout the measurement sequence and the solution removed and replaced by pipette. These techniques will help insure maximum repeatability in a series of measurements.

Flow Cells

Flow cells are recommended for obtaining the highest precision measurements. Use of a flow cell eliminates the necessity of moving the cell between the reference measurement and sample measurement. Moreover, the cell can easily be rinsed thoroughly with the solution to be measured. Test the cell for its washout characteristics to determine rinse time/volume requirements. A sipper arrangement such as shown in Figure 4-1 provides convenient sampling of moderate-sized samples. Refer to page 7-14 for information regarding flow cell and pump installation.

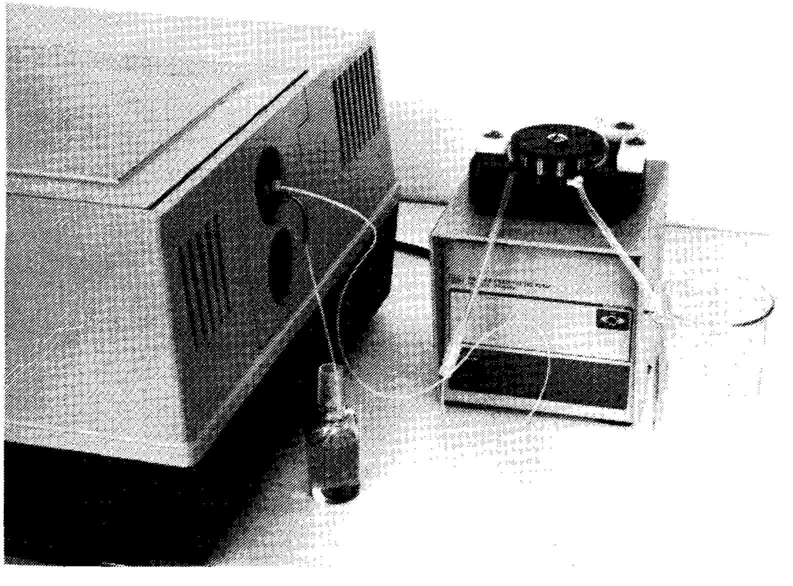


Figure 4-1. Manual Sipper Arrangement

The design of the flow cell should minimize entrapment of bubbles and flow "channeling" to provide the most reliable results. Small volume and ease of cleaning are also desirable features. Measurements of turbid liquids or those containing dispersed particles should be avoided (or averaged over many measurements) due to the unpredictable variations in transmittance during the measurement period.

When monitoring the effluent of a liquid chromatograph, a small cell volume can aid in obtaining the highest resolution of spectral data. The usual column flow rates are low and, if the volume of the cell is also small, there is minimum loss of resolution of the separation.

Cell Placement in the Sample Chamber

The sample chamber is equipped with a standard cell holder which accommodates 1-cm cells. The HP 8451 is shipped with the standard cell holder already installed. When necessary, it may be removed for cleaning by loosening its two thumb screws. Three locating pins on the bottom of the sample chamber ensure that the cell holder can be easily reinstalled in its correct position.

To insert a cuvette in the cell holder, first check that the locking lever is in its up position (see Figure 4-2). Then place the cuvette in the holder and lock it in place by pushing the locking lever down.

Small volume flow cells and particularly any cells with less than a 2-mm aperture may require use of the optional adjustable cell holder (HP 89070A) so that the cell may be properly centered in the light path.

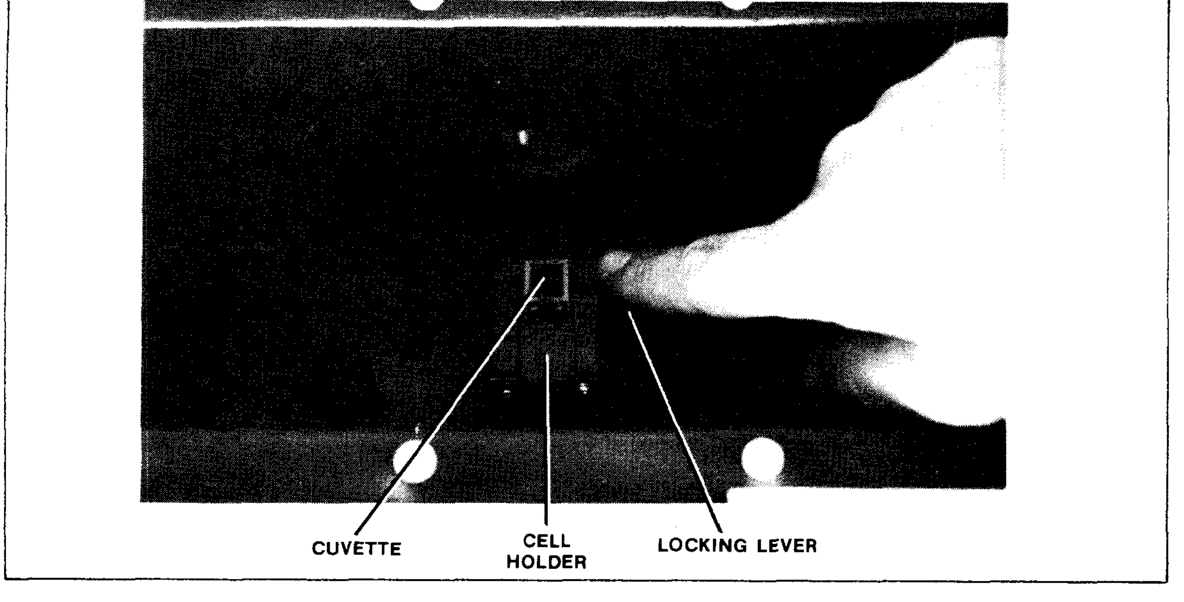


Figure 4-2. Locking the Sample Cell in Position

START-UP INFORMATION

For spectrophotometer operation, the spectrophotometer software (HP Part No. 08451-60103) must be installed before the instrument is turned on. Failure to install the spectrophotometer software will result in the display of ERROR 23: Self Test.

The ON/OFF switch is located at the right rear of the instrument. When power is turned on, the HP 8451 automatically proceeds through a series of internal diagnostic tests. The POWER, MEASURING, and DIAGNOSTIC indicator lights located on the front panel are on during these tests, which require about 15-20 seconds. The instrument start-up status is then displayed on the screen (see Figure 4-3). Information contained in the status report is described on page 4-8.

```
MEASURE 1,0,0,0
LAMBDA 190 TO 820
Y-SCALE AUTO 0 TO 0
output PLOTTER 1
function ABSORBANCE
LAMP TURN-ON
bandwidth 2 nm
7856
```

Figure 4-3. Status Message Displayed at Start-Up

Errors detected during the power-on tests result in the flashing of one or more indicator lights and/or an error message displayed on the screen. Certain error messages are also signaled by a "beep" sound.

The deuterium lamp is automatically turned on after these diagnostics have been passed, but requires about 90 seconds to complete ignition. The instrument status report shows the lamp status as "TURN-ON" to indicate that the turn-on sequence is in progress.

As soon as the instrument status has been displayed, the operator may begin to enter commands. Any commands except measurements are acceptable at this stage.

When the lamp is fully turned on, the LAMP indicator light comes on. Optical system diagnostics are then automatically performed (about a few seconds). When these tests are finished, the MEASURING and DIAGNOSTIC lights go off. At this point, only the POWER and LAMP indicator lights remain on. The instrument is now ready to perform measurements. Note, however, after the lamp comes on and the LAMP indicator is lit, the STATUS report is not rewritten on the screen to say LAMP-ON unless the key sequence PRINTER 1 EXECUTE STATUS EXECUTE is entered.

Indicator Lights

There are five indicator lights on the front panel at the left of the keyboard. They are interpreted as follows:

POWER:	Light is on when the line voltage is on and the secondary power supplies are at the proper voltages.
MEASURING:	Light is on when a measurement is in progress or when certain diagnostic tests are running.
PGM RUNNING:	Light is on when calculations are in progress or when a BASIC program is running.
DIAGNOSTIC:	Light is on when a user-called diagnostic test is running, and during the instrument turn-on diagnostic sequence.
LAMP:	Light is on when the lamp turn-on sequence has been completed and lamp is on.

Lamp Control

The deuterium lamp is automatically turned on when instrument power is turned on. The lamp indicator light on the instrument front panel is on when the lamp is on.

The lamp is turned off by pressing

LAMP 0 EXECUTE

To turn the lamp on again, press

LAMP 1 EXECUTE or

LAMP EXECUTE

INSTRUMENT STATUS

The HP 8451 generates four types of status reports. These give information regarding the current operating parameters, data stored in memory or on disc, and quantitation routines. Table 4-2 summarizes the STATUS commands.

TABLE 4-2. STATUS COMMANDS

Command	Type of Information
STATUS EXECUTE	Current instrument operating parameters, including x-axis, y-scale, data processing, measure parameters, lamp condition, and the designated output devices.
STATUS STANDARD EXECUTE	Contents of STANDARDS stored in memory (see page 4-25).
STATUS FILE EXECUTE	Contents of disc drive files (see page 7-10).
STATUS CONCENTRATION EXECUTE	Relative fit of data stored in STANDARDS to a calculated concentration curve (see page 6-6).
ERASE STATUS EXECUTE	Restores all default operating conditions (but does not erase STANDARDS or FILES).
STATUS MEMORY EXECUTE	Amount of available memory left in external memory. (Requires alphanumeric keyboard and Advanced Techniques Module.)

Displaying the Current Status

In order to display the current operating status of the HP 8451, press

STATUS EXECUTE

This command yields a report of current operating parameters (see Figure 4-4). The information shown in the status report represents the "default" conditions, that is, the conditions which are used unless explicit commands are entered by the operator.

```
MEASURE 1,0,0,0
LAMBDA 190 TO 500
Y-SCALE AUTO 0 TO 3
output PLOTTER 1
function ABSORBANCE
LAMP ON
bandwidth 2 nm
7856
```

Figure 4-4. Example Status Report

MEASURE 1,0,0,0

The current status indicates a single 1-second measurement. Other parameters are for specifying repetitive measurements. See page 4-20.

LAMBDA 190 TO 500

The curent status specifies measurements over the wavelength range from 190 to 500 nm.

Y-SCALE AUTO 0 TO 3

The Y-SCALE is currently under automatic control. The most recent display used a Y-SCALE from 0 to 3. Units are appropriate for the current calculation process.

output PLOTTER 1

The instrument is set to output measurement results to PLOTTER 1 (the CRT screen). See page 4-10 for further information.

function ABSORBANCE

The current data processing function is ABSORBANCE.

LAMP ON

The deuterium lamp is ON. Status may also be TURN-ON (in the process of being turned on) or OFF.

bandwidth 2 nm

The bandwidth of the instrument is 2 nm. That is, the photodiode detectors are centered at the even-numbered nanometer values.

7856

There are 7,856 bytes of memory (one data point requires eight bytes) available for storage of data or programs in memory. The last 500 bytes are reserved for system use, however.

Resetting the Instrument Status

The operator can return to all default values used at turn-on by pressing

[shift] ERASE STATUS EXECUTE

The turn-on defaults are listed in Table 4-3 for reference.

Please note that the ERASE STATUS command does not erase the instrument memory, that is, the STANDARDS which may have been stored, nor does it erase the current reference or sample measurements.

TABLE 4-3. SUMMARY OF TURN-ON DEFAULT VALUES

MEASURE 1,0,0,0	A single 1-second measurement.
LAMBDA 190 to 820	Full HP 8451A range.
Y-SCALE Auto	Automatic scaling of the y-axis appropriate to the data displayed.
Current Plotter: 1	Plotting on CRT.
Current Printer: 2	Printing on built-in printer.
Current Output: Plotter 1	Measurement results are automatically plotted on the CRT.
Function: Absorbance	Data presented as absorbance.
Linetype: 1	Plot drawn with a solid line.
Annotate: Off	No automatic annotation.
Interpolate: 0	Plotting with smooth interpolation between datapoints.
Mode 0, 0	Automatic output of data (to the specified output device) following a MEASURE command.
Mode 1, 0	Standard deviation of data not shown.
Mode 2, 0	Concentration routines use maximum likelihood statistical treatment.
Mode 3, 0	Amplifier gain adjustment automatically performed at the REFERENCE measurement.

EDITING COMMANDS

If you make a mistake while entering a keyboard command, there are three editing keys which can be used to recover:

1. The BACK SPACE key moves the cursor (underscore) backward, erasing characters as it moves.
2. The -LINE ("minus line") key erases all characters from the cursor to the end of the line.
3. The [shift] CLEAR key sequence clears the entire screen.

Notice that when EXECUTE is pressed, the entire line at which the cursor is located is read by the processor. It is therefore necessary to clear unwanted characters (using the -LINE key, typically) before pressing EXECUTE.

The optional alphanumeric keyboard provides additional editing capability. Refer to page 8-7 for use of these additional editing keys.

OUTPUT DEVICES

The HP 8451 can output information in several ways. At any time, the instrument has a current plotter, a current printer, and a current output device for measurements.

At turn-on, the current printer and plotter are assigned to the CRT and the built-in printer, respectively, but may be changed by the operator with commands such as

PRINTER n EXECUTE or

PLOTTER n EXECUTE

where n is the address of the desired device. The number n can be a one-digit internal address used to specify the built-in CRT or printer, or a three-digit external address used to specify an external peripheral device (see page 7-2).

The current output device is simply the most recently assigned printer or plotter. Each of the output devices is explained below.

Plotter

At turn-on, the HP 8451 sends all plotter output to the screen. The screen (or CRT) is called "plotter 1". If the operator wishes plots to be copied on the built-in printer, this operation requires two steps: the plot is generated on the screen by pressing PLOTTER EXECUTE, and then copied by pressing the COPY key.

The designated plotter can also be reassigned, so that plotting on an external plotter is possible. Refer to page 7-2.

Printer

At turn-on, the HP 8451 sends all printer output to the built-in printer. This printer is called "printer 2". If the operator wants printed output to appear on the screen instead of the built-in printer, the command is

PRINTER 1 EXECUTE

which makes the CRT ("printer 1") the current printer. To return printing to the built-in printer, press

PRINTER 2 EXECUTE

Output Device for Measurements

Following each MEASURE command, the results can be sent to the current output device. At start-up, such output occurs automatically. If desired, the operator can disable this automatic output by entering [shift] MODE 0, 1 EXECUTE (see page 5-14). This operation could typically be done to save time during fast repetitive measurements.

The device to which measurement results are sent can be either a plotter or a printer. The type of device determines how the data is presented. For example, if printer 1 is specified as the output device, the measurement result values are printed on the CRT, and no plot is made.

At start-up, the current output device for measurements is plotter 1 (the CRT), and following a MEASURE command, the data is automatically plotted on the CRT.

The operator selects the output device for measurements by printer and plotter commands such as described above. The most recently specified printer or plotter is automatically taken to be the output device for measurements. Refer to the examples shown in Table 4-4.

TABLE 4-4. SELECTING THE OUTPUT DEVICE FOR MEASUREMENTS

Desired Output	Enter
Plotting:	
Plotting on screen*	PLOTTER 1 EXECUTE
Plotting on built-in printer	PLOTTER 1 EXECUTE (After data is plotted on the on the screen, press COPY.)
Plotting on an external plotter (interface 7, HP-IB address 05)	PLOTTER 705 EXECUTE
Printing:	
Printing on screen	PRINTER 1 EXECUTE
Printing on built-in printer*	PRINTER 2 EXECUTE
*Default at turn-on.	

MAKING MEASUREMENTS

This section describes how to make a reference measurement and how to make straightforward absorbance and transmittance measurements. Such measurements only require a few keyboard entries.

NOTE

Before using the commands described below, press

[shift] ERASE STATUS EXECUTE

in order to reset the instrument to the turn-on default values. Refer to Table 4-3 for a list of the default values.

Reference

A reference measurement is required prior to any other measurement. The reference collects and stores in memory the spectrum resulting from a "blank". The blank is usually a cuvette containing the same solvent in which the sample is dissolved. Occasionally, for example when filters are measured, the blank might be a non-absorbing filter, or even "air," that is, an empty sample holder. This spectrum is subtracted from all future measurements in order to compensate for the emission spectrum of the lamp and absorption of the sample cell and the solvent.

Place a clean, rinsed sample cell containing only the chosen solvent in the sample holder. Press the keys

REFERENCE EXECUTE

Such a command automatically performs a 1-second measurement.

The HP 8451 was designed to be a general purpose spectrophotometer. The use of liquid samples in a cuvette with a 10 mm pathlength results in the optimum optical performance. Whenever possible, a liquid reference (i.e., the solvent) should be used for absorbance measurements involving liquid samples. For example, aqueous samples should be referenced against water. The practice ensures accurate results because of comparable light focusing properties for both the reference and the sample.

Although the instrumental drift of the HP 8451 is very small, the highest precision measurements require that a reference measurement be performed immediately before the sample measurement. Otherwise, small changes in the lamp emission and thermally related system conditions are not fully

compensated. In general, a reference measurement should be repeated as often as is practical, but at least every hour or two to assure accuracy. Variation in the ambient temperature makes more frequent reference measurements necessary. In contrast to other measurements, the reference measurement is always performed over the entire wavelength range of the instrument, regardless of the range specified in the current status report. Also, the reference data are always stored as absorbance data, regardless of the data processing shown in the status report.

Absorbance

The absorbance (A) is defined by the equation

$$A = \log \left(\frac{I_0 - D}{I - D} \right)$$

where Io is the average data obtained by a REFERENCE command and I is the average data from a MEASURE command, and D is the dark current.

Following the reference measurement, an absorbance measurement can be performed by replacing the blank solution with the sample and pressing

MEASURE EXECUTE

This command uses a 1-second integration time for the measurement. To perform an 0.9-second measurement, press

MEASURE 0.9 EXECUTE

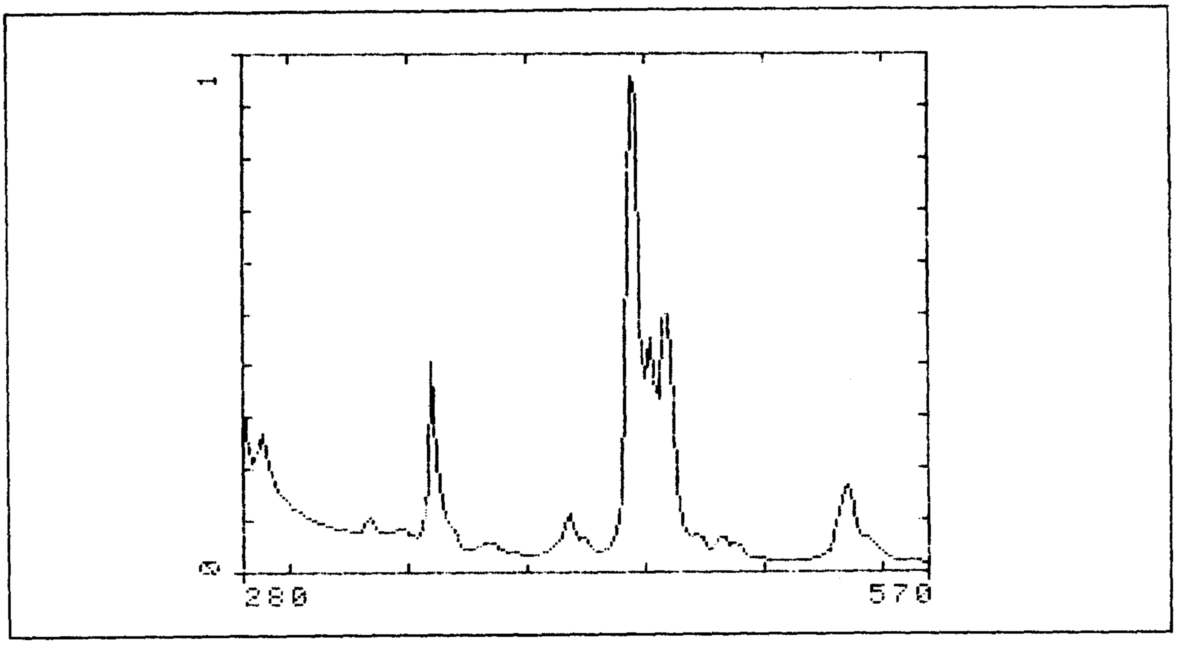


Figure 4-5. Absorbance Spectrum

Once entered as above, the 0.9-second integration time will be used in all future MEASURE commands until explicitly changed, or until the ERASE STATUS command is used to reset the default value to 1 second. The REFERENCE EXECUTE command also restores the integration time to one second. An example absorbance spectrum as copied on the built-in printer is shown in Figure 4-5.

Transmittance

If desired, the operator can select the display of transmittance data rather than absorbance. The transmittance (T) is defined by the equation

$$T = \frac{I - D}{I_0 - D}$$

where I and Io are as defined above.

To select transmittance, press,

TRANSMITTANCE EXECUTE

Place the sample in the cell holder and then press

MEASURE EXECUTE

The instrument measures the absorbance of the sample, then converts the data to transmittance before displaying the spectrum. All data are presented as transmittance values until the operator explicitly changes the data processing, or until the ERASE STATUS command is used to reset the default processing, absorbance.

As above, the integration time for the measurement defaults to a 1-second measurement at the ERASE STATUS command. To perform a shorter measurement, say 0.5 seconds, press

MEASURE 0.5 EXECUTE

The newly entered integration time will be used in all future MEASURE commands until explicitly changed or until reset to 1 second by the ERASE STATUS command.

STANDARD DEVIATION FEATURE

The HP 8451 has the ability to calculate the precision of its results. When a measurement with an integration time longer than 0.9 seconds is made, the instrument actually makes seven or more measurements and calculates the standard deviation of the measurements. This statistical information is only displayed, however, when the operator has turned on the standard deviation feature. See Figure 4-6.

```
350=  .072708 (.00015)
352=  .071151 ( 00018)
354=   06932 (.00612)
356=  .084503 (.00015)
358=  .175369 (.06012)
360=  .410232 (.00026)
362=   209991 (.00018)
364=  .136749 (.00013)
366=  .106674 (.060092)
368=  .090972 (.0001)
370=  .067016 (.0001)
```

Figure 4-6. Absorbance Data with Standard Deviation Shown

If desired, the operator can enter the standard deviation of the concentrations of STANDARDS stored in memory (see page 4-26). If such values are entered, the processor uses these statistics in its CONCENTRATION methods, combining them with the estimated measurement errors to yield a final error estimate for the result.

At turn-on, the HP 8451 calculates, but does not display the standard deviation. To turn on the display of the standard deviation feature, press

[shift] MODE 1, 1 EXECUTE

The standard deviation feature is turned off by the ERASE STATUS command (which resets the instrument to its turn-on status) or by the command

[shift] MODE 1 EXECUTE

FAST MEASUREMENTS

The HP 8451 is capable of operating with very short measurement times. As little as 0.1 seconds is required. The fastest measurement times are only possible, however, by streamlining the measurement protocol.

The standard measurement protocol (used for measurements with integration times of 1.0 second and greater) involves five 0.1-second measurements at each photodiode detector. The results of the 0.1-second measurements are averaged and the variance (the standard deviation squared) is computed. Table 4-5 shows how the number of 0.1-second measurement frames is related to the integration time. For integration and periodicity times of 0.9 seconds and less, only a calculation of the mean is performed.

For integration times of 0.9 seconds and less, the shutter is not closed between measurement frames. Measurement of the dark current is therefore not updated until the end of the sample measurements.

Guidelines for the selection of the optimum measurement interval are given at the end of Section 4, Operation.

TABLE 4-5. RELATIONSHIP OF INTEGRATION TIME TO NUMBER OF MEASUREMENT FRAMES

Integration Time (i) (Seconds)	Number of 0.1-Second Frames	Comment
0.1 to 0.9	1 to 9	Dark current measured for each MEASURE command. No variance computed.
⩾ 1.0	10i - 5	Standard protocol. Dark current taken every repeat cycle.

CHANGING DISPLAY PARAMETERS

Once measured, the HP 8451 retains the current spectrum in memory until it is replaced by a new spectrum. The memory location used for the most recently obtained spectrum is called STANDARD 0. Because a measured spectrum is stored in memory, it is possible to redisplay data over a new wavelength range or with a different y-scale without remeasuring the spectrum. Note however, that only the wavelength region selected at the time of the MEASURE command is actually measured. The sample must be remeasured to obtain data at wavelengths outside the range of those which were selected at the time of the measurement.

It is important to distinguish commands which simply "set up" data processing parameters from those which cause the data processing to be executed. Examples of commands which are simply setting up parameters include:

LAMBDA 200 TO 500 EXECUTE

Y-SCALE 0 TO 1 EXECUTE

TRANSMITTANCE EXECUTE

ABSORBANCE 340 TO 350 EXECUTE

TIME SCALE 0 TO 10 EXECUTE

PEAK FIND EXECUTE

CONCENTRATION 2, 1, 2, 3, 4 EXECUTE

Only four types of commands cause the data processing to actually occur. These commands are:

MEASURE EXECUTE

PLOTTER EXECUTE

PRINTER EXECUTE

CALCULATE EXECUTE (used with optional alphanumeric keyboard only)

Refer to Figure 4-7 for a diagrammatic summary of the data processing scheme.

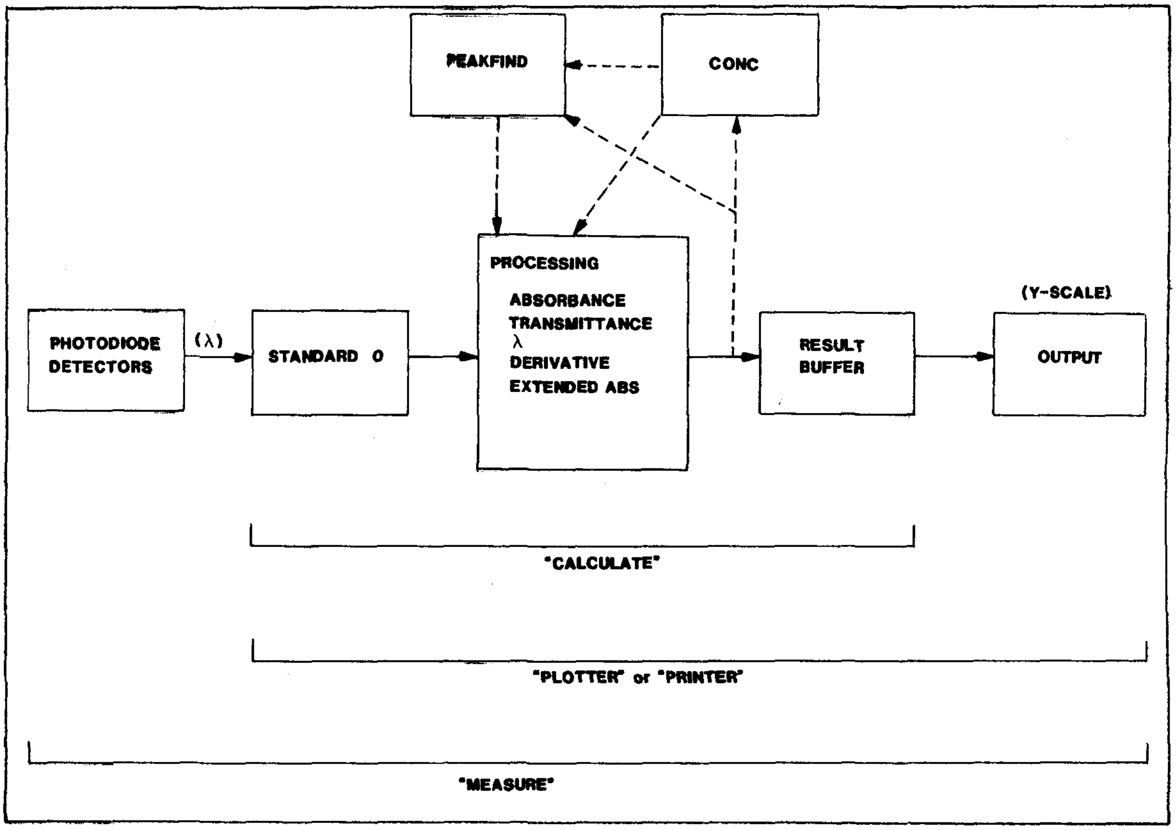


Figure 4-7. Measurement and Data Processing Commands

Wavelength Range

At turn-on, the HP 8451A uses its entire wavelength range, 190 to 820 nm. The HP 8451A has a bandwidth of 2 nm, and the detector has a unique photodiode centered at each even-numbered wavelength value from 190 to 820 nm (316 diodes total). Odd-numbered wavelength values are accepted by the processor but are automatically changed to the next lower even-numbered wavelength before being used.

The wavelength range over which the data are displayed is changed simply by entering the new range, for example:

LAMBDA 400 TO 600 EXECUTE

To display the data again, press

PLOTTER EXECUTE

If desired, the operator can select a list of wavelength values rather than a range, for example:

LAMBDA 400, 500, 510, 540, 600 EXECUTE

Up to 20 wavelengths can be selected. Such a list of values is never plotted, of course, but a list of the values at these wavelengths is printed (on the current printer) at the next MEASURE command.

As with data processing, the wavelength range entered is used in all future measurements and displays until explicitly changed or until reset to the entire range by the ERASE STATUS command.

To reset the wavelength range to the entire range without resetting other parameters, simply press

LAMBDA EXECUTE

Y-Scale

At turn-on, the y-scale is automatically selected as is appropriate to display the data (auto y-scale). If desired, the operator may explicitly specify the y-scale using a command such as

Y-SCALE 0 TO 2 EXECUTE

When so specified, the y-scale remains the same until explicitly changed by a new command. The y-scale is reset to the automatic y-scaling by pressing

Y-SCALE EXECUTE or

[shift] ERASE STATUS EXECUTE

The advantage of using the automatic y-scale is that the y-scale is automatically adjusted each time the display is changed. The y-scale units are whatever units are appropriate to the data processing which was performed. They might be transmittance units, absorbance units, or units resulting from processing of the data by a CONCENTRATION routine.

Changing Data Processing

Data which are present in memory, either in STANDARD 0 or the result buffer (see Figure 4-7), are accompanied by a label which tells what type of data is present. The "type" is always one of the following:

ABSORBANCE

TRANSMITTANCE

DERIVATIVE n, m

DATA

If the function is a derivative, the order (n) and number of points used for smoothing (m) are specified in the label. The "DATA" type is used for data processing which is not one of the first three types. Examples of processing which result in "DATA" include

ABSORBANCE 200 TO 400

ABSORBANCE * 2.4

ABSORBANCE / 3

The significance of the "type" is that it is used to determine what further data processing can be done. It is clear, for example, that once data is converted to the third derivative, it cannot be converted back to absorbance data. To do so would require integration, including knowledge of the integration constant. This information is not stored.

Possible data processing is summarized in Table 4-6.

TABLE 4-6. DATA PROCESSING

Data Type	Further Processing		
	Simple Absorbance	Transmittance	Derivative
ABSORBANCE	OK	OK	OK
TRANSMITTANCE	OK	OK	not allowed
DERIVATIVE	not allowed	not allowed	OK[1]
DATA	OK[2]	not allowed	OK

1. Only allowed if the same derivative order and smoothing is requested.
2. Data treated like ABSORBANCE.

Extended Calculations

There are circumstances in which the operator may wish to perform data processing on data which has already been treated. If the data type is either ABSORBANCE or DATA, further processing is not restricted in any way (see Table 4-6).

If the data is currently of the TRANSMITTANCE or DERIVATIVE type however, the processor does not recognize further data manipulation directly. It is possible to treat the data further, but it must be treated as an "extended ABSORBANCE" calculation. An "extended ABSORBANCE" calculation begins with the ABSORBANCE key and contains either a range of values or one or more arithmetic operations. Consider the case in which a transmittance spectrum was measured and stored in STANDARD 1 some time previously. If the operator wishes to recall this STANDARD and multiply it by a factor of 2, for example, the commands which should be used are as follows:

RECALL STANDARD 1 EXECUTE

ABSORBANCE * 2 EXECUTE

PLOTTER EXECUTE

Notice that "TRANSMITTANCE * 2" is not acceptable. The data which result from the above commands actually ARE twice the transmittance, but the processor only recognizes as extended calculations those beginning with "ABSORBANCE". What happens internally is that the data (transmittance in this case) are taken as is and further modified. They are not converted back to absorbance data as it might appear.

Refer to the description of the ABSORBANCE key (page 5-3) for further examples.

REPETITIVE MEASUREMENTS

Measurements may be made repetitively over a period of time by using an extended form of the MEASURE command. To measure the sample every 5 seconds for 1 minute, the operator might use the following command:

```
MEASURE 1, 5, 0, 60 EXECUTE
        ↑  ↑  ↑  ↑
        i  r  s  e
```

where i = integration time
r = repeat time
s = starting time after EXECUTE
e = ending time after EXECUTE

The example command above measures the samples with a 1-second integration time, every 5 seconds, starting immediately after EXECUTE is pressed, and ending 60 seconds after the EXECUTE.

The total number of measurements performed is equal to

INT [(e - s) / r] + 1

or 13 measurements in the above example.

Measuring a Series of Single Values

Time-based measurements can be performed at a single wavelength, for example

[shift] ERASE STATUS EXECUTE (resets all defaults)

LAMBDA 500 EXECUTE

MEASURE 1, 5, 10, 300 EXECUTE

The results of this measurement sequence are shown in Figure 4-8.

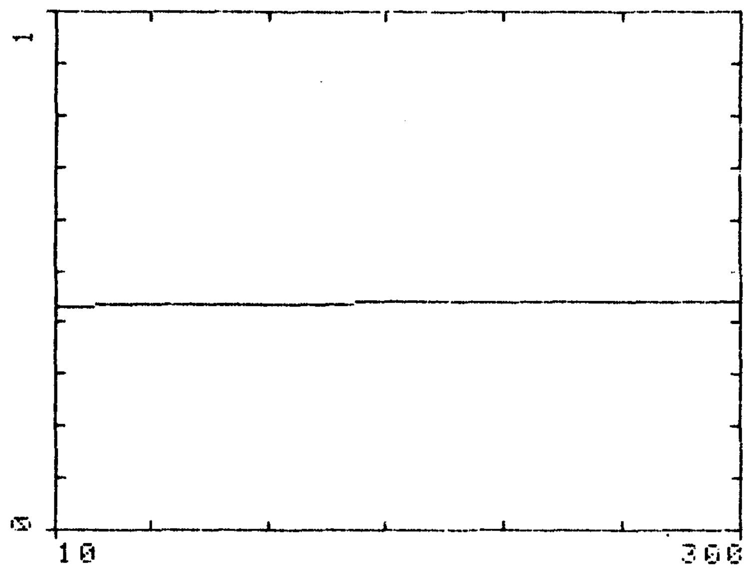


Figure 4-8. Time-Based Measurement at a Single Wavelength

The results of the measurements are plotted as they are obtained. Since the automatic y-scale was selected, a preliminary y-scale of 0 to 1 is selected. When the measurements are completed, the data can be rescaled and redisplayed by pressing PLOTTER EXECUTE.

If you know what y-scale is appropriate for the expected results, simply specify the y-scale before beginning the measurement series.

The total number of data points which can be accumulated in memory as part of a time-based series is 320. If more than this number are obtained, only the last 320 values are retained.

Data Processing During Time-Based Measurements

Following each individual measurement in the series, the processor calculates the results according to the function shown in the status report, then plots the results. If the function is a simple one such as absorbance at a single wavelength, the results can be computed and displayed very rapidly. In such cases, the repeat time can be very short. For example, the command sequence

ABSORBANCE EXECUTE

LAMBDA 340 EXECUTE

MEASURE 0.1, 0.1, 0, 10 EXECUTE

performs measurements every 0.1 second with an integration time of 0.1 second.

More complex processing, such as collecting the data over a wavelength range, averaging the data, and then plotting requires more time. For example,

LAMBDA 200 TO 400 EXECUTE

ABSORBANCE 200 TO 400 EXECUTE (calculates average absorbance)

PLOTTER 1 EXECUTE

MEASURE 1, 2, 0, 30 EXECUTE

If the processor is unable to complete the processing and display the results before the next measurement is scheduled, the message

ERROR 111: MEASURE INTERVAL

is displayed, indicating that the measurement interval is too short for the specified processing. You should then increase the repeat time, decrease the integration time, narrow the wavelength range, or simplify the requested data processing.

You might also consider disabling the automatic output (by pressing [shift] MODE 0, 1 EXECUTE), thereby eliminating the real-time display. The data can then be collected and processed as before, but to save time are not displayed.

Following the last measurement in a series of time-based measurements, the data reside both in STANDARD 0 and in the result buffer and are termed "ABSORBANCE". This data type is assigned regardless of the previous data processing.

If desired, the data can be stored in the processor memory (in a STANDARD).

Time Scale

When time-based measurements are performed at a single wavelength or are processed to yield a single result for each measurement time, the x-axis is a time scale in seconds. The operator can redisplay the data over a different time range, analogous to changing the wavelength range as described above.

NOTE

You may get an error message if the data processing function is not ABSORBANCE.

The time range over which the data are displayed is changed by entering a command such as

TIME SCALE 10 TO 20 EXECUTE

To redisplay data over this new range, press

PLOTTER EXECUTE

A list of time scale values can be selected rather than a range, for example:

TIME SCALE 0, 10, 20, 25, 40 EXECUTE

Up to 20 time scale values may be selected. Such a list of values is not plotted, but a list of the measured values at these times is printed at the next MEASURE command.

To return to a display of all the time-based data, press

TIME SCALE EXECUTE or

[shift] ERASE STATUS EXECUTE

The latter command resets all instrument operating parameters (see Table 4-3).

Derivatives of Time-Based Data

A time-based series is frequently measured in order to follow the progress of a chemical reaction. In such cases the derivative of the data can be calculated to yield the reaction rate.

Assume that a series of absorbance values at 500 nm had been obtained as follows:

LAMBDA 500 EXECUTE

MEASURE 1, 1, 0, 60 EXECUTE

The resulting 61 values would be plotted on the CRT over a time scale range of 0 to 60 seconds.

To take the derivative of the data, simply enter:

DERIVATIVE EXECUTE

PLOTTER EXECUTE

The DERIVATIVE EXECUTE command specifies the first derivative with 3-point smoothing. These are the default values. (See page 5-6 for further information on the DERIVATIVE key.)

At PLOTTER EXECUTE, the derivative is calculated and replotted on the CRT. The slope (derivative) is calculated at each data point except for the first few points and the last few points since at least three points are required to determine the slope.

An average of some or all of these derivative values requires use of some extended calculations.

Measuring a Series of Spectra

Repetitive measurement of a wavelength spectrum (more than a single value) is performed as described for measuring a series of single values except that the data are not accumulated in memory as part of a time-based series.

The following series of commands,

ABSORBANCE EXECUTE

PLOTTER 1 EXECUTE

LAMBDA 200 TO 280 EXECUTE

MEASURE 1, 5, 0, 60 EXECUTE

produces thirteen sequential spectra displayed on the CRT. After the last measurement, however, only the final spectrum is retained in STANDARD 0.

If there is sufficient time, the data can be automatically output to a printer or to an external plotter, thus yielding a permanent record of the results. Using a BASIC program, it is also possible to store the sequential spectra on disc. Refer to Section 8.

STORING DATA IN MEMORY: "STANDARDS"

There are 99 locations in the processor memory where data can be stored. These memory locations are called STANDARDS, and are identified by the numbers 1 to 99. The location which contains the most recently obtained data is termed STANDARD 0. This memory location is over-written at each MEASURE (or RECALL) command, and differs from the other memory locations in its temporary nature. All internal memory is volatile, however, in that loss of power results in loss of all stored information. Figure 4-9 shows schematically how data is stored in, and recalled from, STANDARDS.

The types of data which can be stored in a STANDARD include:

1. A complete spectrum or portion of a spectrum (one spectrum per STANDARD).

2. An absorbance or transmittance spectrum, the derivative of such a spectrum, or some other arithmetic function of a spectrum.

3. A series of measurements at a single wavelength, or processed to yield a single value, obtained over a specified time period (one time-based series per STANDARD).

4. A single value such as the absorbance at one wavelength, average absorbance over a wavelength range, or the ratio of absorbance at one wavelength to that at another wavelength.

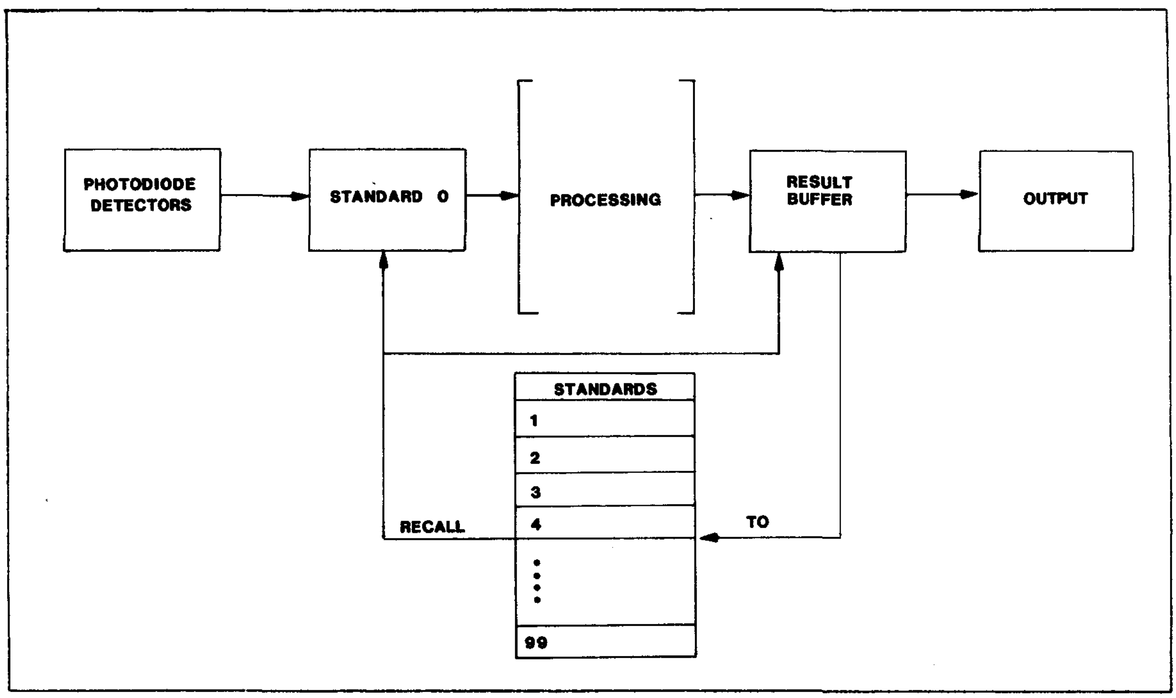


Figure 4-9. Storing and Recalling STANDARDS

Creating Standards

Following a measurement, the data obtained can be stored in memory by a command such as

TO STANDARD 1 EXECUTE

The STANDARD number can be 1 to 99. The data are stored with the wavelength range and type of data processing which were specified at the most recent MEASURE, PLOTTER, or PRINTER command.

When data are stored in a STANDARD, it is also possible to record the concentration of the sample, the standard deviation of the concentration, and a name for the STANDARD. The entry of the optional name requires the alphanumeric keyboard. An example of such an entry is:

TO STANDARD 1, 5.2, 0.1, "RUN 1" EXECUTE

This command stores the current data in STANDARD 1, stores its concentration as 5.2 with a standard deviation of 0.1, and gives it the name RUN 1.

Note that the data that are recorded in a STANDARD are obtained from the result buffer, and therefore have the wavelength range, and data processing which were in effect at the most recent MEASURE, PLOTTER, or PRINTER command. If you wish to change the wavelength range or data processing before storing the data in a STANDARD, you must change the processing, then execute a MEASURE, PLOTTER, or PRINTER command in order to cause the new processing to be performed, and finally, store the data. For example, suppose the entire wavelength range was measured:

[shift] ERASE STATUS EXECUTE

MEASURE EXECUTE

The entire wavelength range is now in the result buffer. To store only the region from 200 to 400 nm, enter the following commands:

LAMBDA 200 TO 400 EXECUTE	Sets up new range
PLOTTER EXECUTE	Processes data using the new wavelength range
TO STANDARD 1 EXECUTE	Stores the data over the new range in STANDARD 1

Memory Size

The standard HP 8451 instrument has about 8000 bytes of memory available for storing data (in STANDARDS) and BASIC programs. One program can be stored in memory at any one time.

If the HP 8451 has the optional 16K Memory Module (HP 82903A) installed, it provides an additional 16,000 bytes of memory. A total of about 24,000 bytes are then available for storage of STANDARDS and a program. An optional 128K Memory Module is also available. Its use is described on page 7-12.

Each STANDARD requires 104 bytes for its "header" information plus eight bytes for each data point. For example, a STANDARD consisting of data over the range from 190 to 510 nm (with a bandwidth of 2 nm) contains 161 data points and therefore requires 104 + 8 (161) = 1392 bytes of memory. The standard instrument can therefore store (8000/1392), or five such spectra, while an instrument with the optional 16K Memory Module can store seventeen such spectra. For maximum use of the instrument memory, store only the wavelength range of interest.

The memory which is currently available is displayed in the STATUS report (page 4-8), except that the last 500 bytes are reserved for internal use.

Listing Stored Standards

The operator can generate a list of all standards currently stored in memory by entering the command

STATUS STANDARD EXECUTE

An example of such a report is shown in Figure 4-10. The report includes standard numbers, names (if any), concentrations, and sizes (bytes of memory used). A list of a range of standards may also be generated, for example,

STATUS STANDARD 20 TO 30 EXECUTE

STD	NAME	CONC	SIZE
20		1	312
21		1	112
22		1	232
23		00122	232
24		1	208
25		5 256	112
26		1	208
27		1	208
28		1	208
29		.156	232
30		1	112

Figure 4-10. Status Report Showing Multiple STANDARDS

NOTE

> The optional standard deviation of the concentration is displayed only if MODE 1 is enabled. To do so, press [shift] MODE 1, 1 EXECUTE.

More detailed information about a particular STANDARD can be obtained by a command such as

STATUS STANDARD 1 EXECUTE

If the STANDARD contains data over a wavelength range, the status report includes the standard number, name, concentration, type of data (the "function"), and wavelength range or list of wavelengths. See Figure 4-11.

```
STD 29
conc .156
type: ABSORBANCE
LAMBDA  200 TO 230
```

Figure 4-11. Status Report for a STANDARD over a Wavelength Range

If the STANDARD contains a series of measurements over a time period, the status report includes the standard number, name, concentration, type of data, time range (or list of time values), and time interval between values. See Figure 4-12.

```
STD 15
conc 1
type: ABSORBANCE
TIME 0 TO 20
INTERVAL 1
```

Figure 4-12. Status Report for a Time-Based STANDARD

Recalling Standards

The data stored in a STANDARD is accessed by "recalling" the STANDARD with a command such as

RECALL STANDARD 11 EXECUTE

Such a command brings the stored data both to STANDARD 0 and to the result buffer (see Figure 4-9). To observe the data, press PLOTTER EXECUTE or PRINTER EXECUTE, as appropriate.

The concentration and function information for a STANDARD is accessed using a STATUS STANDARD command (see page 4-28).

Editing Standards

If you forgot to enter the concentration of a STANDARD when it was originally stored, or otherwise wish to edit the name or calculation, it is not necessary to remeasure the sample. Simply edit the standard as follows:

RECALL STANDARD 1 EXECUTE (Bring the data to STANDARD 0)

[shift] ERASE STANDARD 1 EXECUTE (Clears the location STANDARD 1)

TO STANDARD 1, 0.2, 0.1, "name" EXECUTE

The data are then again stored in STANDARD 1 with the new concentration and name information.

Moving Standards

If you wish to move a STANDARD from one memory location to another, you can do so very easily. To move STANDARD 1 to STANDARD 30, for example, enter:

RECALL STANDARD 1 EXECUTE

TO STANDARD 30 EXECUTE

The name and concentration of STANDARD 1 will automatically be moved to STANDARD 30 along with the data.

Transfer of information in STANDARDS to disc drive files is accomplished similarly:

RECALL STANDARD 1 EXECUTE

TO FILE 15 EXECUTE

Refer to the description of disc drive operation (page 7-8) for further information.

Erasing Standards

STANDARDS are erased from the processor memory either individually or by a range:

[shift] ERASE STANDARD 17 EXECUTE

[shift] ERASE STANDARD 10 TO 20 EXECUTE

All STANDARDS stored in memory are erased using the command

[shift] ERASE STANDARD EXECUTE

SELECTING THE OPTIMUM MEASUREMENT PARAMETERS

As a particular analysis method is developed, the choice of measurement parameters is an important part of the overall optimization of the analysis procedure. Because the HP 8451 is a general purpose UV/VIS Spectrophotometer samples can range from common industrial solvents to high molecular weight biological samples. Similarly, sample cell size can range from eight microliters in LC applications to several milliliters in standard cuvettes. These samples can be spectrophotometrically analyzed with increased speed by passing wideband radiation through the sample during a measurement.

Due to the high data acquisition rate, many discrete measurements of a sample can be made in a single integration period. This allows the system to achieve lower noise levels as well as to determine the statistical mean and standard deviation of each result. The user is provided with the result and a measure of its significance. Normally, the decision regarding the significance of the data is left to the analyst. However, the HP 8451 system firmware is capable of detecting when the relationship between a result and its true significance is fundamentally inappropriate. When a result doesn't meet all the conditions of the firmware algorithms, the data is invalidated. When a data point is invalidated, that data point is eliminated from the HP 8451 display. Therefore, only the data that meets certain statistical criteria is displayed.

When data invalidation occurs there are gaps in the wavelength or time-based data. An example of invalid data points in an absorbance versus wavelength plot is shown in Figure 4-13. Procedural and measurement related errors are the major cause of spectral gaps in the HP 8451 display.

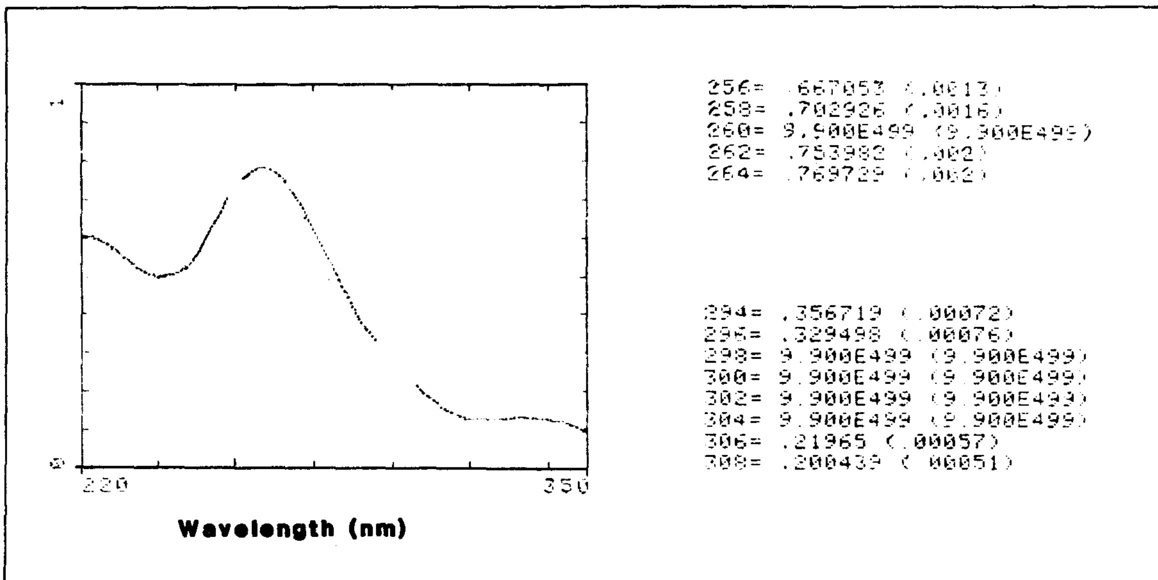


Figure 4-13. Spectral Gaps Caused by Data Invalidation

In the discussion that follows, an examination of the standard deviation of the individual sample data points can provide a measure of the statistical confidence that can be associated with a given result. For integration times of one second or longer, the standard deviation is calculated and used to determine when data is statistically invalid. For such measurements the standard deviation is calculated but is not normally displayed. After a measurement has been displayed, the standard deviation can be displayed by entering the commands:

MODE 1,1 EXECUTE/ Enables the standard deviation data display

PRINTER EXECUTE/ Prints the measurement results and standard deviation for data in the result buffer.

The corresponding absorbance and standard deviation values for selected wavelengths are shown in Figure 4-13. Note that for wavelengths 260, 298, 300, 302 and 304 nm both the absorbance and standard deviation values are displayed as 9.900E499. These statistically invalid data points account for the gaps in the spectra shown in Figure 4-13.

There are several experimental situations in which statistical invalidation of data may occur. These include: (1) insufficient warm-up time, (2) improper reference procedure, (3) sample related dynamics (e.g. large absorbance changes in the sample during the integration period), and (4) electronic failures.

Lamp Warm-Up

If spectral measurements are made before the lamp output has stabilized, changes in the lamp intensity between the reference and a sample measurement can be great enough to cause data points to be invalidated. At least 15 to 20 minutes are required for adequate lamp warm-up. A REFERENCE or LAMP command initiates a photodiode amplifier gain adjustment routine. The individual photodiode gain factors established during this time are used for all subsequent measurements until another REFERENCE or LAMP command is executed. This has the effect of optimizing the signal levels before the analog to digital conversion is performed. If the lamp intensity increases significantly over time, the gain factors established at the time of the reference measurement can cause over amplification of sample measurement signals and result in ADC (Analog to digital converter) saturation. If this occurs, the value for the affected data point is invalidated. After the warm-up period, a lamp drift test can be performed to verify proper lamp intensity stability (see Section 9).

The most direct method of optimizing the photodiode amplifier gain factors is by a REFERENCE or LAMP command. This method establishes the proper gain for each of 316 photodiodes (190nm to 820nm in 2nm steps) to one of 16 possible values (i.e. intensity n,m where the diode amplifier gain m=0,1,2,...15).

Inappropriate Reference

For the most accurate measurement, the reference and the sample and the sample materials should be closely matched. Ideally, the only difference between the reference and the sample material should be the presence of the analyte(s). For measurements of liquid samples a solvent filled cuvette (or flow cell) should be in place when the reference measurement is made. Given the unique index of refraction and absorption characteristics of each solvent, the amplifier gain adjustment routine performed at a REFERENCE command should be done with a reference material similar to the sample material.

Whenever possible, the solvent should have low absorption in the wavelength region of analytical interest. For best results, the analytical wavelength(s) should be outside the UV cutoff region of the solvent (see Table 4-1) and away from major solvent absorption bands. By definition, the transmittance of light through any medium is significantly reduced in the wavelength region where an absorption band exists. In general, the lower the transmitted light intensity, the lower the sensitivity. This occurs because the signal to noise ratio is reduced. For an absorbance value of 3au, only 1/1000th of the original light intensity will pass through the sample. Even though the HP 8451 will adjust the gain factor so that the signal level for analog to digital conversion is optimized, the system noise is amplified by the same factor as the signal of interest. At some point the signal is indistinguishable from the noise and no meaningful spectral data can be extracted.

In general, a reference measurement should be repeated as often as is practical. To ensure accurate results in a thermally stable environment, a reference measurement should be made at least every hour.

In some cases where sample data points are invalidated, repetitive MEASURE commands with the sample in place will result in fewer of the data points being invalidated. This occurs because of short term changes in the sample dynamics. If the degree of data invalidation is reduced through the use of repetitive MEASURE commands, the reference material (or the measurement parameters) must be changed in order to obtain optimal spectroscopic results.

Negative absorbance occurs when the reference material transmits less light than the sample. For the HP 8451 default parameters, negative absorbance values to approximately -0.05 to -0.1 au are possible (the actual limit depends on the absolute intensity at the individual diodes). As shown below, the useable negative range can be extended when required.

For specialized applications, the amplifier gain adjustment routine that is normally initiated during a REFERENCE measurement can be disabled by the command.

MODE 3,1 EXECUTE

When MODE 3 is enabled, only the LAMP command will initiate an amplifier gain adjustment routine. Besides reducing the length of time required for the REFERENCE measurement, this may be useful for samples that exhibit

negative absorbance. For those cases where high negative absorbances are expected, the following procedure may be used.

1. Execute a LAMP command while a highly transmittant substance (e.g. water or "air") is in the light path. This will optimize the gain for the highest throughput possible.

2. Execute the MODE 3,1 command to disable the automatic gain adjustment routine.

3. Make a REFERENCE measurement on a solvent filled cuvette.

4. Measure the sample absorbance. The comparitive advantage of enabling MODE 3 for samples that show negative absorbance is shown in the data of Figure 4-14.

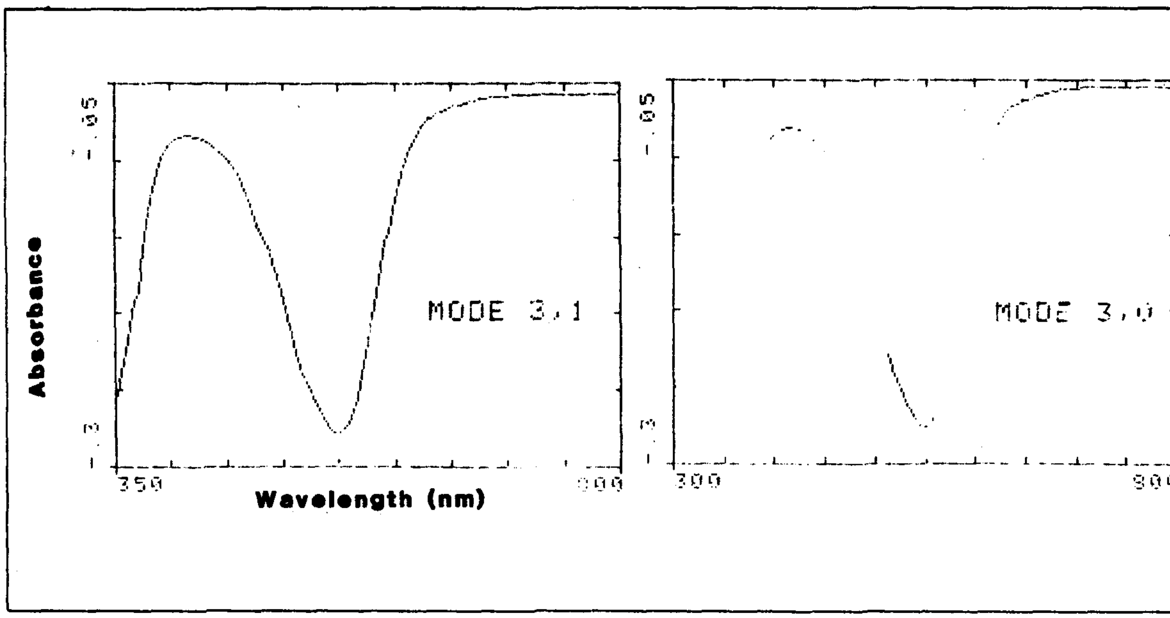


Figure 4-14. Negative Absorbance Measurement Using MODE 3

Sample-Related Dynamics

In cases where the sample is undergoing absorbance changes in the time domain, the relationship between integration time and sample related signal change becomes important. If the sample dynamics have short time constants with respect to the integration time, significant measurement errors can result. If the sample data points do not meet certain statistical criteria, the HP 8451 invalidates the affected range of data as a protection of data integrity. If data invalidation occurs in the wavelength domain, the spectrum will be displayed with gaps in those regions where the data is invalid (see Figure 4-13).

Some of the algorithms used in the HP 8451 for data validity are based on the changes in intensity at each photodiode over the integration time. The simplest of these algorithms checks the deviation in counts from time t(1) to time t where t(1) corresponds to the first data frame. If the intensity changes by more than 255 counts during the integration time, the data is invalidated.

In time domain measurements the integration times should be matched to the sample dynamics. If the integration time is long, a rapid chemical change can result in system invalidation of the data that shows the highest rate of change. This type of statistical invalidation should signal the user to reduce the integration time to something more appropriate to the chemical rate of change that is actually occurring.

In cases where a long integration time is required for highly dynamic samples, the BASIC language operating system can be used to average data from a series of measurements of short integration time (see Section 8). Such an approach will reduce the possibility of data invalidation due to inadvertant sample dynamics.

Spectral and time domain measurements taken in dynamic chemical situations where invalidation might occur with long integration times are:

1. Process stream analysis where valving or slug flow changes take place. If the shape of the new fluid front is desired, a short integration will be required.

2. High performance LC situations in which the integration time is long with respect to peak elution width. The integration time should be chosen to produce at least 5 to 10 data points per peak. Since the diode array is a true integrating device, no quantitative information is lost.

3. Kinetic measurements, either due to normal, catalytic, or photo induced reactions, need an integration time that is at least three to five times shorter than the time constant of the reaction being studied in order to adequately reflect the kinetic structure.

4. Inadvertant Dynamics. For certain samples, the act of making the spectral measurement can cause the sample absorbance characteristics to change. In such cases, data invalidation may result. This type of data invalidation may be eliminated by choosing an integration time short enough to ensure that the amount of light exposure does not induce absorbance changes in the sample. Other parameters that can be adjusted by the analyst to eliminate the occurance of inadvertant dynamics are sample residence times and the incident light characteristics. With the proper measurement parameters, the spectra of compounds such as Rhodopsin, the photosensitive pigment of the eye, have been successfully measured using the HP 8451.

The Effects of Stirring

The beam of the HP 8451 is very small at the sample to allow full performance measurements of microliter volumes. Therefore, in a standard cell, solution uniformity can be an issue expecially for solutions of high viscosity. There are a few cases, where due to convection induced concentration gradients from high or low temperature samples, rapid absorbance changes can be seen that may invalidate the data. These types of fluctuations may be observed spectroscopically by choosing short integration times. This may be eliminated by thermostating and/or stirring the sample. The same effect can also be seen in cases of incomplete mixing especially where the specific gravity or miscibility of the reagent and sample have a high degree of mismatch.

In an unstirred cell, it may be possible to observe local photo-degradation of sensitive samples. Because the actual volume of sample in the light path is very small, stirring the sample will reduce the residence time of individual analyte moietes in the beam and minimize the photosensitivity considerations. Figure 4-15 shows the effect of stirring (or flow) on a particularly photosensitive sample. Initially, a pump moved the sample through a flow cell and the spectral transmittance remained constant. When the flow was stopped the transmittance began to decrease. This occurred because the electronic structure of the sample was changed during the measurement.

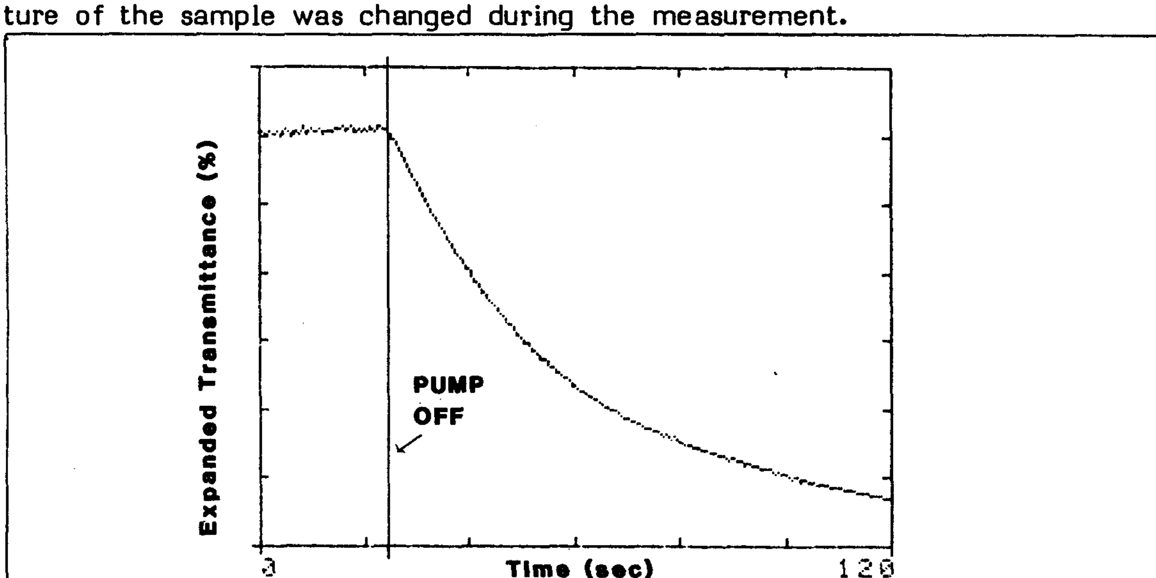


Figure 4-15. Transmittance Versus Sample Residence Time

In some cases the transmittance change is only temporary and the sample will relax to its premeasurement state. In other cases, samples may be photolytically changed because of the measurement. In the static situation, the number of incident photons/time of sufficient energy to induce spectral changes in the sample was significant enough to result in a measurable transmittance change for the finite number of molecules in the light path. When the pump was on, new sample molecules were continuously flowing through the cell and the mean residence time of given molecules in the light beam was short enough so that photolytic reactions were minimized.

To a lesser extent, the degree of this effect in static situations is related to the cuvette characteristics. A standard 1 cm cuvette has a larger sample volume and hence greater molecular diffusion volume than an apertured micro liter cell. Therefore, a static sample in a standard cuvette will be less likely to exhibit photosensitivity behavior during the spectral measurement. Likewise, whenever the molecular diffussion rates are increased (i.e., increased sample temperature) molecules move in and out of the light path quicker and are less likely to exhibit data invalidation during the spectral measurement.

Use of Filters

If an overall reduction in the light intensity is required to prevent the occurance of sample photodegradation during a spectral measurement, neutral density or wavelength cut-off filters may be used. The use of such filters between the light source and the sample has enabled the spectra of chemicals used in the photographic processes to be measured using an HP 8451.

If a specific sample is sensitive to certain spectral regions, a filter can be added to cut out unwanted spectral exposure. Shorter wavelength, higher energy UV radiation has the greatest potential degrading photosensitive samples. Portions of the UV spectrum may be selectively blocked by a UV cut-off filter.

If a UV cut-off filter is placed between the lamp and the sample, the incident radiation that reaches the sample is dependent on the transmission characteristics of the cut-off filter. Figure 4-16 shows a filter that has a UV cut-off at 300 nm. The use of such a filter would prevent radiation of 300 nm or less from reaching the sample. Whenever a filter is used during a sample measurement, it is required for the reference measurement as well. The choice of the wavelength cut-off should be low enough to retain useful analytical spectral information and high enough to block radiation that may degrade the photosensitive sample. A four position filter wheel designed for use with the HP 8451 is described in Section 7, Accessories.

Barring electronic failures, insufficient warm-up, and improper reference, measurement parameters should be chosen so that data is meaningful and no data invalidation occurs in the spectral region of interest. Whenever data invalidation occurs, it is to alert the user of a fundamental problem with the spectral measurement. The most common situation occurs when the integration time is too long to properly represent the sample absorbance changes that are occuring. The range of measurement intervals available to the analyst are 0.1 seconds to 25.4 seconds. Usually, integration times longer than 5 seconds yield little or no improvement in signal to noise ratio. The default integration time of one second produces at least five sample measurements, a dark measurement and statistics information at each wavelength chosen. This is an optimum measurement interval for most samples in equilibrium conditions. For photosensitive samples, shorter measurement intervals should be used. For measurement intervals in the 0.1 to 0.9 second range, no statisctics information is calculated.

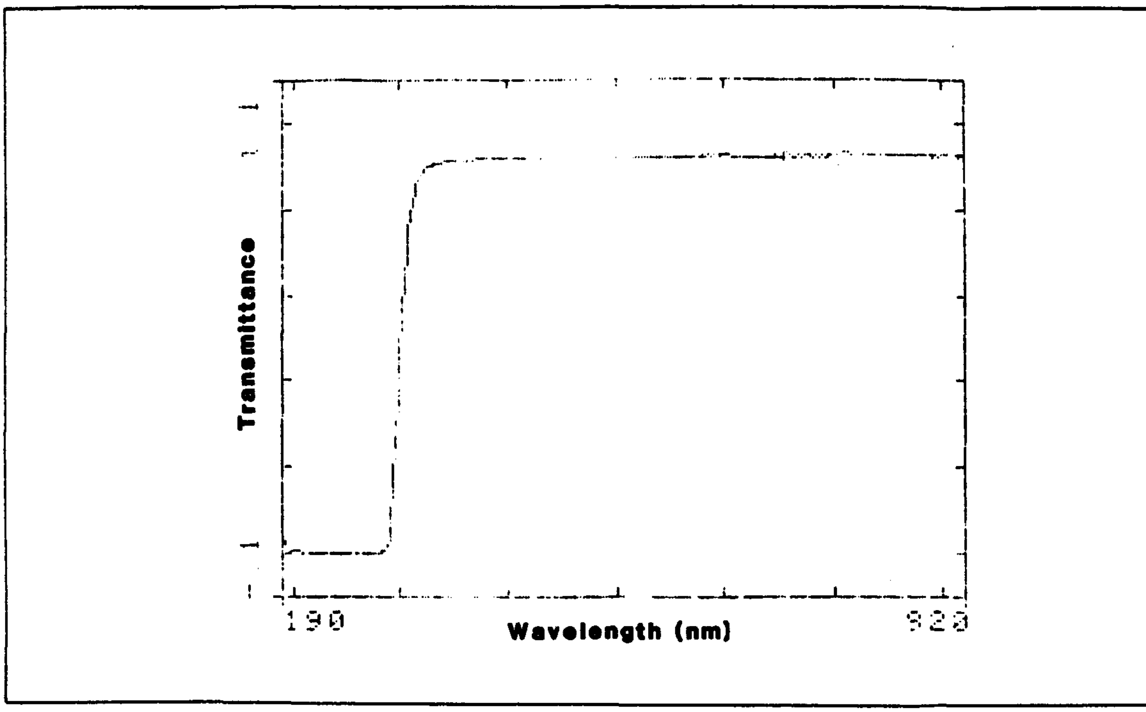


Figure 4-16. Transmission Characteristics of a UV Cut-Off Filter

System Noise

Occasionally some instrumental limitation, such as measurements being made at very high absorbance, or a true problem with the instrument, will invalidate data due to excessive noise in the measurement. Isolation of electronic problems can be facilitated by using the intensity diagnostics discussed in Section 9.

Section 5

KEYBOARD COMMANDS

INTRODUCTION

This section gives a detailed description of each of the keys on the standard HP 8451 keyboard. Use of the optional alphanumeric keyboard is described in Section 8.

It is intended that this section be used for a quick reference to the correct usage of common keyboard commands. Keys are listed in alphabetical order for convenience. Examples are included to help illustrate the appropriate command formats. A condensed version of this section appears in the pull-out cards located under the front right of the instrument.

KEYBOARD ARRANGEMENT

The standard keyboard of the HP 8451 Diode Array Spectrometer is shown in Figure 5-1. The keyboard is arranged such that the general flow of command entries is from left to right. The EXECUTE key, used at the end of commands to initiate action, is at the lower right corner of the keyboard. Frequently used keys, PLOTTER, REFERENCE, and MEASURE are in the top row at the left. Keys which are used for specifying the x- and y-axis display parameters, Y-SCALE, LAMBDA, and TIME SCALE, are grouped above the numeric keys since they are often used together. The TO key, used to set a range of numbers, is just to the left of the numbers at the bottom of the keyboard.

COMMAND SYNTAX

In the descriptions given below, some commands are illustrated with a general form such as:

FILE n [,m]

In such cases, the small letters n and m are numeric parameters which are defined in the description of the command. Parameters (such as n above) which are not in brackets are a required part of the command. Optional parameters (such as m above) are enclosed in brackets. In this example m (if used) must be separated from n by a comma.

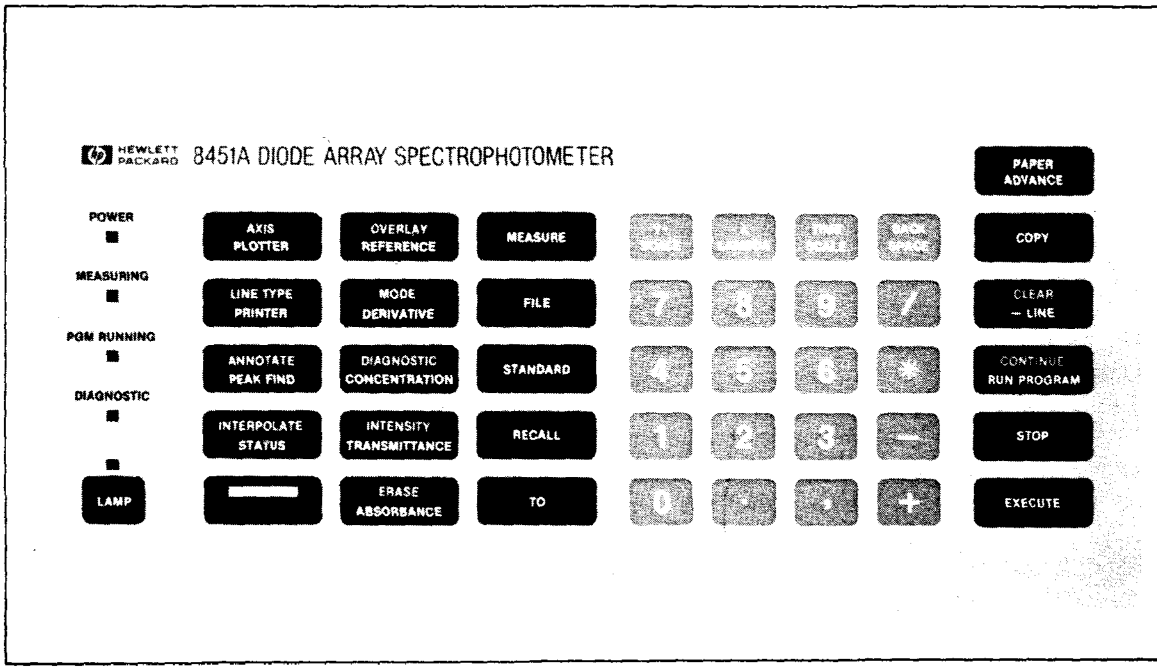


Figure 5-1. Standard HP 8451 Keyboard

[SHIFT]

The key with the yellow bar is used as a prefix to allow the operator to access the functions printed in yellow. Simply press it prior to selecting any function written in yellow letters.

KEY DESCRIPTIONS

Numerics: 0 through 9

These keys are used to enter numeric values.

The numeric range limits are as follows:

Integers: -99,999 to +99,999

Real Numbers: $-9.99999999999 \times 10^{-499}$ to $9.99999999999 \times 10^{+499}$

Measured values are represented internally with a six-digit mantissa and a three-digit exponent.

Arithmetic Operators: * / + -

These keys are the arithmetic operators for multiplication, division, addition, and subtraction. The HP 8451 can be used like a calculator for simple entries such as the following:

4.23 * 15 EXECUTE

716 + 15 / 3.4 EXECUTE

When an expression contains more than one operator, the arithmetic hierarchy is that multiplication and division are performed first, and addition and subtraction are performed last. When an expression contains two or more operators at the same level of hierarchy, the order of execution is from left to right.

ABSORBANCE

The ABSORBANCE key is used to set the data processing to absorbance such that results are expressed in absorbance units. It is the default mode of data processing established at start-up and by the ERASE STATUS command. To reset the data processing to ABSORBANCE at any time, press

ABSORBANCE EXECUTE

The ABSORBANCE key is also used to specify extended calculations. The general format for such commands is as follows:

ABSORBANCE [X1 [TO X2]] [A N] [A N] ... EXECUTE

where X = wavelength in nm, time in seconds, or a variable from a BASIC program.

A = arithmetic operator (+, -, *, or /)

N = a number, a STANDARD, or another ABSORBANCE function (ABSORBANCE X3 TO X4).

The expression [A N] can be repeated up to six times or until the command fills three CRT lines. If N is a STANDARD, specify STANDARD n where n is the STANDARD number (1 to 99) or a variable from a BASIC program. When more than one arithmetic parameter is present, the expression is evaluated strictly from left to right, <u>not</u> following the normal hierarchy.

The extended ABSORBANCE functions can be used to calculate averages or ratios of absorbance, to subtract spectra from each other, to multiply or divide the absorbance values by absorptivities or dilution factors, and so on.

Example 1: To multiply the absorbance at 340 nm by a concentration factor of 3.1, enter:

ABSORBANCE 340 * 3.1 EXECUTE

Example 2: To subtract STANDARD 7 from the current absorbance data, enter:

ABSORBANCE - STANDARD 7 EXECUTE

The two spectra are subtracted at all common wavelengths (or time values).

Example 3: To subtract the absorbance at 350 nm from that at 254 nm, enter:

ABSORBANCE 254 - ABSORBANCE 350 EXECUTE

Example 4: To calculate the average absorbance from 210 to 220 nm, enter:

ABSORBANCE 210 TO 220 EXECUTE

Note that the LAMBDA key is not used.

Example 5: To calculate the ratio of absorbance at 210 nm to the average absorbance between 400 and 450 nm, enter:

ABSORBANCE 210 / ABSORBANCE 400 TO 450 EXECUTE

ANNOTATE

The ANNOTATE key is used to set up to 20 wavelength (or time) values at which a plot on an external plotter is to be labeled. The proper format is as follows:

[shift] ANNOTATE p1, p2, p3, ... EXECUTE

where the values p1, p2, and so on are the x-axis values at which the plot is to be annotated.

To prepare to label a plot which covers the range 200 to 400 nm at the values 300 nm, 320 nm, and 340 nm, enter the following command:

[shift] ANNOTATE 300, 320, 340 EXECUTE

Then execute the plot on an external plotter using the command PLOTTER EXECUTE. After the data has been plotted, the labels at wavelengths 300, 320, and 340 are added automatically.

To remove annotation from subsequent plots, press:

[shift] ANNOTATE EXECUTE

or [shift] ERASE STATUS EXECUTE (resets all defaults)

AXIS

The AXIS key is used to draw the x- and y-axes when a plot has been drawn on an external plotter. First plot the data with the command PLOTTER EXECUTE, then press

[shift] AXIS EXECUTE

to draw the axes and label the plot with the x- and y-scale. The processor automatically selects the scale appropriate to the data.

The AXIS command automatically resets the linetype to a solid line.

BACK SPACE

The BACK SPACE key is used for editing incorrect keyboard entries. Pressing this key once moves the cursor (underscore) one space to the left, erasing the character which was displayed. Holding the BACK SPACE key down repeats the cursor movement and erasure.

CLEAR

The CLEAR key clears the entire screen.

COMMA

The comma is used for separating multiple numeric entries.

CONCENTRATION

The CONCENTRATION key is used to specify data processing involving the calculation of the concentration of either a single component or several components. The general command format is as follows:

CONCENTRATION n, std [,std [,std [...]]] EXECUTE

where n = concentration method (0 to 4)
stds = STANDARD numbers stored in memory (1 to 99). Up to 12 stds may specified.

n	Type of calibration curve	Min. Number of STANDARDS Required
0	straight line; intercept through zero	1
1	straight line; non-zero intercept	2
2	second order; intercept through zero	2
3	second order; non-zero intercept	3
4	multicomponent analysis	1 for each component

To specify a single component analysis using concentration method 3 and four stored STANDARDS, numbers 10, 11, 12, and 13 enter

CONCENTRATION 3, 10, 11, 12, 13 EXECUTE

To specify a multicomponent analysis using two STANDARDS, numbers 8 and 9, enter

CONCENTRATION 4, 8, 9 EXECUTE

The CONCENTRATION processing remains in effect until a new CONCENTRATION command is entered, a new function is entered (absorbance, transmittance, etc.), or until the ERASE STATUS command is executed.

CONTINUE

The CONTINUE key is used to cause a BASIC program to resume after a pause. It is not necessary to press EXECUTE; however, [shift] must precede CONTINUE.

COPY

The COPY key can be used at any time to copy the information displayed on the screen onto the built-in printer.

DECIMAL

The decimal point is used to enter numeric values.

DERIVATIVE

The DERIVATIVE key is used to take derivatives. Up to the seventh derivative may be specified. It also designates smoothing of the data over a specified number of data points. The smoothing algorithm employed is the Savitsky-Golay method. √

The command format is as follows:

DERIVATIVE [n [,p]] EXECUTE

where n = derivative order (1 to 7, default = 1)
p = number of smoothing points (3 to 31, odd; default = 3)

For example, to obtain the sixth derivative with nine-point smoothing, enter:

DERIVATIVE 6, 9 EXECUTE

Press MEASURE EXECUTE, PLOTTER EXECUTE or PRINTER EXECUTE to output the results.

DIAGNOSTIC

The DIAGNOSTIC key is used to access any of nine different diagnostic routines which test the instrument operation. The format for DIAGNOSTIC commands is as follows:

[shift] DIAGNOSTIC n [,m] EXECUTE

where n = number of the test (0 to 8)
m = number of repetitions (1 to 32767, default = 1)

n	Test	Error Result
0	Flash keyboard lights	Lights don't flash
1	CPU	Number of errors reported
2	ROM	Number of errors reported
3	RAM	Number of errors reported
4	DMA	Number of errors reported
5	Multiplier	Number of errors reported
6	Timer/Interrupt	Number of errors reported
7	System RAM and ROM	Number of errors reported
8	CRT and built-in printer	Observe CRT and printer for errors

To run the multiplier test 50 times, enter:

[shift] DIAGNOSTIC 5, 50 EXECUTE

At the end of the repetitions of a test, the message END TEST is printed. See Section 9, Maintenance, for a complete description of each test.

ERASE

The ERASE key is used in four types of commands: (1) to reset instrument operating parameters, (2) to erase data stored in memory (STANDARDS), (3) to erase data stored on flexible disc (FILES), and (4) to initialize flexible discs.

1. Resetting Instrument Status

   The HP 8451 is returned to its start-up condition, with all operating parameters set to their default values by entering the command:

   [shift] ERASE STATUS EXECUTE

   This command does not erase the STANDARDS or program which may be stored in memory. See Table 4-3 for a complete list of the start-up operating parameters.

2. Erasing STANDARDS

   Data stored in STANDARDS (locations in memory) are erased by commands such as:

   [shift] ERASE STANDARD (erases all STANDARDS)

   [shift] ERASE STANDARD 6 EXECUTE

   [shift] ERASE STANDARD 6 TO 8 EXECUTE

3. Erasing FILES

   Data stored on flexible disc may be erased by a command of the format:

   [shift] ERASE FILE n [,m] EXECUTE

   where n = file number (1 to 999999)
   m = disc drive code (if not the current disc drive)

   To erase a single file (number 83) from the currently designated disc drive, enter:

   [shift] ERASE FILE 83 EXECUTE

   To erase file number 83 from an alternate disc drive (number 701), enter:

   [shift] ERASE FILE 83, 701 EXECUTE

   See page 7-9 for an explanation of disc drive designations.

4. Initializing Discs

   To initialize the disc inserted in the currently designated disc drive, enter:

   [shift] ERASE FILE - 1 EXECUTE

   CAUTION: This command erases the entire disc and formats it for use with the HP 8451.

EXECUTE

The EXECUTE key is used to terminate keyboard entries and to initiate any action that was described by the previous keyboard commands on the CRT.

FILE

The FILE key is used with the TO and RECALL keys to store data on a flexible disc or to recall the data into the instrument data buffer. The operator can also request the STATUS of files or ERASE files. The FILE is specified according to the format:

FILE n [,m]

where n = file number (1 to 999999)
m = three-digit address of disc drive (if not the currently designated drive)
1st digit: interface select code (7 for HPIB)
2nd digit: controller address (0 to 7)
3rd digit: drive number (0 to 3)

Example 1: To store the current data on the currently designated disc drive as file number 15, enter:

TO FILE 15 EXECUTE

Example 2: To store the current data on an alternate drive (number 701) as file number 15, enter:

TO FILE 15, 701 EXECUTE

Example 3: To recall the data from file number 18 on the currently designated disc drive, enter:

RECALL FILE 18 EXECUTE

Example 4: To obtain a listing on the CRT of all data and programs stored on the currently designated disc drive, enter:

STATUS FILE EXECUTE

See Figure 7-4 for an example.

Example 5: To obtain information on a particular file (number 37) on drive 701, enter:

STATUS FILE 37, 701 EXECUTE

Example 6: To erase this file, enter:

[shift] ERASE FILE 37, 701 EXECUTE

INTENSITY

The INTENSITY key is used to cause photometric measurements to be reported as the actual photodiode signal outputs, uncorrected for the REFERENCE spectrum. Its primary use is in adjusting the position of a narrow-apertured flow cell or in checking for decreased source lamp intensity (see page 9-17).

The general command format is as follows:

[shift] INTENSITY n [,m] EXECUTE

where n = intensity mode (0 to 3)
m = photodiode gain setting (0 to 15; default = 0)
m is defined only for n = 1 or 3

n	
0	intensity at current gain setting
1	intensity at specified gain setting m
2	dark current at current gain setting
3	dark current at specified gain setting m

For example, to specify an intensity measurement utilizing the current gain settings, enter:

[shift] INTENSITY 0 EXECUTE

To exit the INTENSITY mode and reset the proper gain settings, enter:

LAMP EXECUTE

INTERPOLATE

The INTERPOLATE key is used to select either straight line or smooth curve interpolation between data points plotted on an external plotter. At turn-on, a smooth curve is used.

To change to straight line interpolation, enter:

[shift] INTERPOLATE 1 EXECUTE

Straight line interpolation is faster, and for broad peaks, is negligibly different from smooth line interpolation.

To return to smooth line interpolation, enter:

[shift] INTERPOLATE 0 EXECUTE

or [shift] ERASE STATUS EXECUTE (resets all defaults)

LAMBDA

The lambda key is used to specify wavelengths (in nanometers). The operator can select a range of wavelengths, a single wavelength, or a list of up to 20 wavelength values.

LAMBDA 190 TO 500 EXECUTE

LAMBDA 237 EXECUTE

LAMBDA 200, 210, 215, 320, 600 EXECUTE (up to 20 values)

Only the wavelengths shown in the status report are actually measured at a MEASURE command.

To reset the wavelength range to the full range, enter:

LAMBDA EXECUTE

LAMP

The LAMP key is used to turn the deuterium source lamp on and off. To turn the lamp on, press LAMP EXECUTE. To turn the lamp off, press LAMP 0 EXECUTE. LAMP is also used to terminate the intensity mode. If the lamp is already on when a LAMP command is performed, only an amplifier gain adjustment is performed.

-LINE

The "minus line" key is used for editing commands. Pressing this key clears the command line from the position of the cursor (underscore) to the end of the line.

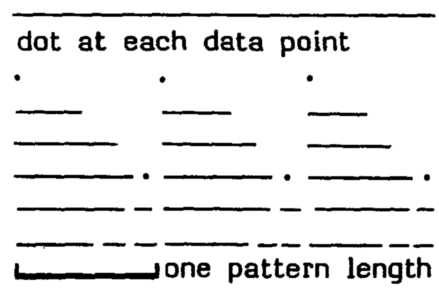
LINETYPE

The LINETYPE key is used to select any of eight different styles of plotting line for use on an external plotter. The operator can also select the length (l) of the repeat pattern, and thus further extend the number of choices of plotting line. The parameter l specifies the length of one complete pattern and is expressed as a percentage of the diagonal distance between the scaling points P1 and P2. The command format is as follows:

[shift] LINETYPE n [,l]

where	n = 1 to 8	(default = 1)	pattern number
	l = 1 to 100	(default = 4)	pattern length

n=1
n=2
n=3
n=4
n=5
n=6
n=7
n=8



The linetype must be specified prior to executing the plot. To select line type 5 (long dashes) with a repeat length 50% longer than the default, enter:

[shift] LINETYPE 5, 6 EXECUTE

Then press PLOTTER EXECUTE. The data is plotted with the linetype and pattern length selected.

For n=2, a dot is placed at each data point. Note, however, that when the plotted line is a smooth curve resulting from the default interpolation, the curve has many calculated data points between the original data points. To plot only the original points, you must first select straight line interpolation. The correct sequence is as follows:

[shift] INTERPOLATE 1 EXECUTE (straight line interpolation)

[shift] LINETYPE 2 EXECUTE

PLOTTER EXECUTE

The linetype is reset to the default (a solid line) by pressing STOP, ERASE STATUS, or AXIS, or by selecting a new plotter with a command such as PLOTTER 1 EXECUTE.

MEASURE

The MEASURE key is used to perform photometric measurements. Either single or multiple measurements may be specified. The general command format is as follows:

MEASURE [i [, r, s, e] EXECUTE

where i = integration time (0.1 to 25.5 seconds)

r = repeat time (i to 99999 seconds)
s = start time (0 to 99999 seconds)
e = end time (s to 99999 seconds)

Defaults: MEASURE 1, 0, 0, 0

All parameters may be specified to the nearest 0.1 second. If all parameters are omitted, the parameters currently shown in the instrument status are used; that is, the most recently entered parameters are used again. If only i is entered, r, s, and e are set to zero and a single measurement is performed.

NOTE

Measurement of a REFERENCE spectrum resets the MEASURE parameters to a single measurement with integration time (i) the same as used in the REFERENCE. The other MEASURE parameters (r, s, and e) are set to 0.

In a series of measurements, the first measurement occurs at time s. If s is zero, this means immediately after the EXECUTE key is pressed.

The total number of measurements in a repetitive measurement is given by the following equation:

$$\text{Total Measurements} = \text{INT}\,[\,(e - s)/r\,] + 1$$

where the INT function means take the integer value only (truncate all fractions).

Example 1: To perform a single 1-second measurement enter:

MEASURE 1 EXECUTE

Example 2: At start-up (or following an ERASE STATUS command) a single 1-second measurement is specified by entering:

MEASURE EXECUTE

Example 3: To measure repetitively, using an integration time of 1 second, measuring every 5 seconds, starting immediately upon EXECUTE, and ending 64 seconds after EXECUTE, enter:

MEASURE 1, 5, 0, 64 EXECUTE

A total of INT [(64 - 0)/5] + 1 = 13 measurements are performed at this command.

Example 4: To repeat the measurement sequence described in Example 3, enter:

MEASURE EXECUTE

Example 5: To return to a single 1-second measurement following a repetitive measurement, enter:

MEASURE 1 EXECUTE

MODE

The MODE key is used to implement several auxiliary capabilities of the HP 8451. The general format for the MODE command is:

[shift] MODE n [,m] EXECUTE

where n = the number of the mode, 0 to 4
m = 0 to disable (turn off) the mode
m = 1 to enable (turn on) the mode
default m = 0

To turn a MODE on (enable it), enter:

[shift] MODE n, 1 EXECUTE

To turn a MODE off (disable it), enter:

[shift] MODE n, 0 EXECUTE

or [shift] MODE n EXECUTE

All MODES are reset to their defaults by the ERASE STATUS command.

1. MODE 0: Automatic Output after MEASURE

   When MODE 0 is turned off, the MEASURE command results in automatic output of the results to the designated output device. When MODE 0 is turned on, results from MEASURE commands are not output automatically. The operator must press PLOTTER EXECUTE or PRINTER EXECUTE to output the results. When MODE 0 is enabled, the status report shows "output OFF".

2. MODE 1: Standard Deviation Feature

   When MODE 1 is turned off, the standard deviation of photometric data is calculated but is not displayed. The optional standard deviation for the concentration of a STANDARD is similarly not displayed. When MODE 1 is turned on, the standard deviations are displayed when the values are printed.

3. MODE 2: Statistical Treatment

   When MODE 2 is turned off, a maximum likelihood statistical treatment is used for CONCENTRATION calculations. When MODE 2 is turned on, a least squares statistical treatment is used in CONCENTRATION calculations. See page 6-1 for further information.

4. MODE 3: Amplifier Gain Adjustment

   When MODE 3 is turned off, the amplifier gain is adjusted for each photodiode following a REFERENCE measurement. This gain adjustment compensates for the lamp emission spectrum being more intense at some wavelengths than others. While such an adjustment is usually advantageous, it does take several seconds. If time is crucial and a REFERENCE measurement must be made in the minimum time, MODE 3 can be enabled causing the amplifier gain adjustment to be omitted.

5. MODE 4:

   This MODE is not turned on or off as the others, but is simply executed by the command

   [shift] MODE 4 EXECUTE

   Such a command causes the flexible disc in the current disc drive to be repacked. The repacking operation rewrites information stored on the disc in the smallest possible space, thus freeing space for additional files.

OVERLAY

The OVERLAY key is used to simultaneously display more than one spectrum on the CRT. It is not used with external plotters.

To set up the CRT for a series of overlaid spectra, press:

[shift] OVERLAY X(min), X(max), Y(min), Y(max) EXECUTE

where: X(min) = smallest x-axis value
X(max) = largest x-axis value
Y(min) = smallest y-axis value
Y(max) = largest y-axis value

For example, the command

[shift] OVERLAY 200, 400, 0, 1 EXECUTE

sets an x-axis range of 200 to 400 nm (or seconds) and a y-axis range of 0 to 1.

The spectra are now displayed by MEASURE commands, or RECALL of STANDARDS followed by PLOTTER EXECUTE. Figure 5-2 shows an example in which 13 spectra were overlaid on the CRT. Any number of spectra can be simultaneously displayed using the OVERLAY technique.

The OVERLAY mode is terminated by a change of x-axis or y-axis, by pressing STOP, by an ERASE STATUS command, or by entering

[shift] OVERLAY EXECUTE

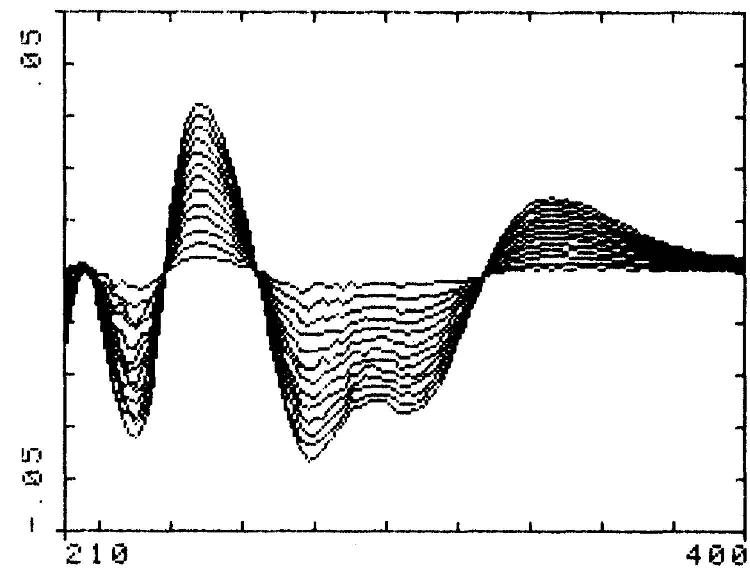


Figure 5-2. Overlay of Spectra on CRT

PAPER ADVANCE

The PAPER ADVANCE key is used to advance paper on the built-in printer. Pressing this key briefly moves the paper one line. Holding the key down moves the paper until the key is released.

PEAK FIND

The PEAK FIND key is used to locate up to 20 peaks. The peaks may be maxima of any plotted data: absorbance, derivatives, transmittance, etc. The proper format for the command is

PEAK FIND n EXECUTE

where n = 0 to 100 (default 0.3)

The parameter n is the percent difference between the maximum and minimum ordinates of the current display limits that defines the threshold

used for peak detection. For n = 3, a peak is detected if a wavelength or time peak (time peaks must have been previously collected) exceeds a 3% change in rise and fall. The definition allows for the detection of peaks on spectral shoulders.

For the spectral data of Figure 5-3, a value of n = 3 produces information on six peaks. For the same data, a value of n = 25 only produces information on two peaks. The number of peaks detected may be reduced by: increasing the value of n, narrowing the wavelength (or time) range, or increasing the Y-scale range.

The choice of n can have a small effect on the location of the peak. For the PEAK FIND data shown in Figure 5-3, the wavelength of the first peak detected changes from 362 nm to 364 nm as the value of n changes from 3% to 25%. The peak location is defined as the midpoint between the signal rise and fall. For critical peak detection, the value of n should be chosen so that [(maximum - minimum) ordinates]/100 is just above the experimental noise.

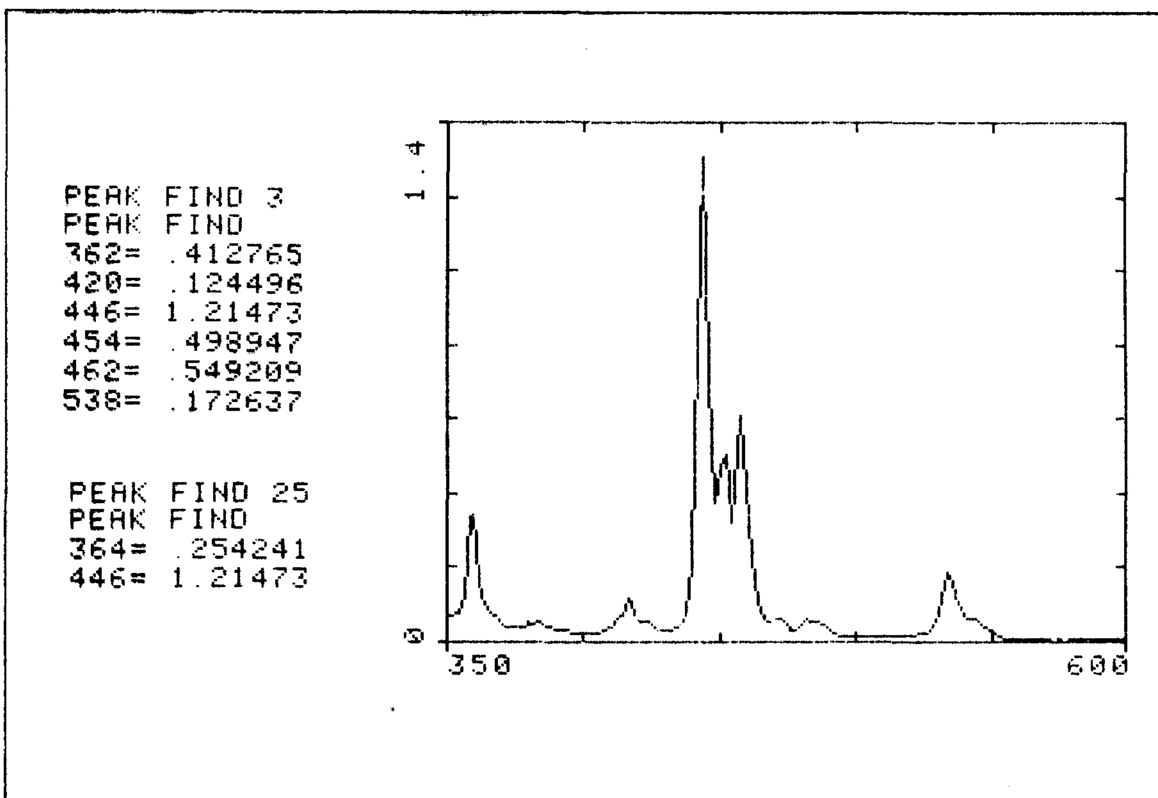


Figure 5-3. Example PEAK FIND Report

The PEAK FIND key can be used to locate the position of valleys by displaying the negative of the data. Instead of the function ABSORBANCE, for example, enter:

ABSORBANCE - ABSORBANCE - ABSORBANCE EXECUTE

The result is the negative of the absorbance, and the valleys will now be located by a PEAK FIND command.

Output of the PEAK FIND report occurs at the following commands:

MEASURE EXECUTE

PLOTTER EXECUTE

PRINTER EXECUTE

The PEAK FIND report is automatically output to the currently designated printer. This mode of operation allows the operator to obtain a plot of the data on the CRT as well as a list of peaks on the printer. For example, suppose the default operating conditions are in effect: output device for measurements is the CRT, designated printer is the built-in printer. If the operator now enters

PEAK FIND EXECUTE

MEASURE EXECUTE

the spectrum is measured and plotted on the CRT, and the PEAK FIND report is printed on the built-in printer.

An exception to this mode of output occurs when the designated output device is an external plotter. In this case, the command PLOTTER EXECUTE causes the data to be plotted on the external plotter, and the peaks located by the PEAK FIND processing are then annotated on the plot. See Figure 7-2 for an example.

PEAK FIND processing is cleared by entry of a new function, by the ERASE STATUS command, or by the command:

PEAK FIND 0 EXECUTE

PLOTTER

The PLOTTER key is used to execute plots on either the built-in CRT or on external plotters. Two types of commands occur: (1) designation of the plotter to be used, and (2) the actual plotting operation.

1. Plotter Designation

The plotter which is to be used is designated by a command such as:

PLOTTER n EXECUTE

For plotting on the CRT, n is 1, so enter:

PLOTTER 1 EXECUTE

For plotting on an external plotter, the numeric parameter is a three digit number. The first digit is the interface select code (3 to 9). Plotters are almost always interfaced via HPIB using the factory set select code, 7. The last two digits of the numeric parameter are the HPIB address of the plotter. The HPIB address is user-selectable from 0 to 31, and is set on the plotter by a binary code. The factory set HPIB address for plotters is 05. (If necessary, refer to the operator's manual for the plotter in order to set this address on the plotter.) To designate plotting on an HPIB plotter using interface select code 7 and HPIB address 05, enter:

PLOTTER 705 EXECUTE

Once the plotter has been so designated, all plots are performed on that device until explicitly changed by the operator. Entering a PLOTTER command as above also designates that plotter as the output device for measurements. (See page 4-10 for further information.) The command

[shift] ERASE STATUS EXECUTE

resets the plotter to its default, the CRT.

2. Plotting

The command PLOTTER EXECUTE causes the data currently in memory (STANDARD 0) to be treated according to the currently specified data processing, and then to be plotted on the currently designated plotter.

The data processing includes the display limits, the function processing (absorbance, transmittance, etc.), and CONCENTRATION or PEAK FIND processing, if any.

PRINTER

The PRINTER key is used to print data or reports on the built-in printer, the CRT, or on external printers. It can also be used to send data to a computer. There are two types of command: (1) designation of the printer to be used, and (2) the actual command to print.

1. Printer Designation

The printer which is to be used is designated by a command such as:

PRINTER n EXECUTE

n = 1 for the CRT
n = 2 for the built-in printer

For printing on an external HPIB printer, the numeric parameter is a three digit number. The first digit is the interface select code (3 to 9). Printers are usually interfaced via HPIB using the factory set select code, 7. The last two digits of the numeric parameter are the HPIB address of the printer. This address is user-selectable from 0 to 31, and is set on the printer by a binary code. The factory set HPIB address for printers is 01. (If necessary, refer to the operator's manual for the printer in order to set this address on the printer.) To designate plotting on an HPIB printer using interface select code 7 and HPIB address 01, enter:

PRINTER 701 EXECUTE

For printing on an external printer which is interfaced via RS-232, n is 10. To designate such a printer, enter:

PRINTER 10 EXECUTE

To output data to a computer interfaced at the RS-232 port, that port is designated for output by entering:

PRINTER 10 EXECUTE

Once the printer has been designated as above, all printed reports are sent to that device until it is explicitly changed by the operator. Entering a PRINTER command such as those shown above also designates that printer as the output device for measurements. (See page 4-10 for further information.) The command [shift] ERASE STATUS EXECUTE resets the plotter to its default, the built-in printer.

2. Printing

The command PRINTER EXECUTE causes the data currently in memory (STANDARD 0) to be treated according to the currently specified data processing, and then to be output on the currently designated printer.

The data processing includes the display limits, the function processing (absorbance, transmittance, etc.) and CONCENTRATION or PEAK FIND processing, if any.

RECALL

The RECALL key is used to retrieve data stored in memory (STANDARDS) or on flexible disc (FILES).

1. Recalling STANDARDS

   To transfer the data stored in a STANDARD to the data buffer, enter:

   RECALL STANDARD n EXECUTE

   where n = standard number (1 to 99)

2. Recalling FILES

   To transfer the data stored in a flexible disc FILE to the data buffer, enter:

   RECALL FILE n [,m] EXECUTE

   where n = file number (0 to 999999)
   m = disc drive code (if not the currently designated disc drive)

3. To output the result, use a PLOTTER or PRINTER command.

REFERENCE

The REFERENCE key is used to measure a "blank" spectrum, usually the spectrum of pure solvent. The appropriate command format is:

REFERENCE [i] EXECUTE

where i is the integration time (0.1 to 25.5 seconds); default = 1

The command REFERENCE EXECUTE performs a 1-second measurement, and stores the spectrum in memory for subtraction from each subsequent measurement. See page 4-12 for further information.

NOTE

> The REFERENCE spectrum is measured and stored for the entire wavelength range of the instrument regardless of the wavelength limits currently shown in the status report. In addition, a gain adjustment procedure is executed.

RUN PROGRAM

The HP 8451 is able to run a BASIC program currently in memory or to load and run a program from the flexible disc. To load and run a program from disc using the functional keyboard, its name and number must be in the format: PGM n. To run a program currently in memory, press:

RUN PROGRAM EXECUTE

To load and run a program stored on disc, enter a command of the format:

RUN PROGRAM n [,m] EXECUTE

where n = number of the program (1 to 99999)
m = disc drive code (if not the currently designated drive)

For example, to run program 5 stored on the current disc drive, enter:

RUN PROGRAM 5 EXECUTE

To run program 5 stored on drive 701, enter:

RUN PROGRAM 5, 701 EXECUTE

See page 7-9 for an explanation of disc drive designations.

STANDARD

The STANDARD key is used to refer to data stored in the instrument memory. Four types of commands are common: (1) storing the data, (2) recalling the data, (3) listing the STANDARDS which are currently stored, and (4) erasing the STANDARDS. The stored STANDARDS can also be used in extended calculations (see ABSORBANCE, page 5 -3).

1. Storing STANDARDS

The command format is:

TO STANDARD n [,c [,s]] [,"name"] EXECUTE

where n = standard number (1 to 99)
c = concentration value (default = 1)
s = standard deviation of the concentration (default = 0)
name = an optional name entered with the alphanumeric keyboard (8 characters maximum)

For example, to store the data currently in the result buffer in the location called STANDARD 10 with a concentration of 4.12 and a standard deviation of 0.05, enter:

TO STANDARD 10, 4.12, 0.05 EXECUTE

2. Recalling STANDARDS

   To retrieve the data stored in a STANDARD and place it in the current data buffer, enter:

   RECALL STANDARD n EXECUTE

   where n = standard number (1 to 99)

3. Listing STANDARDS

   To list a single STANDARD, number 6, enter:

   STATUS STANDARD 6 EXECUTE

   To list a range of STANDARDS, numbers 10 to 30, enter:

   STATUS STANDARD 10 TO 30 EXECUTE

   To list all STANDARDS stored in memory, enter:

   STATUS STANDARD EXECUTE

4. Erasing STANDARDS

   To erase a single STANDARD, number 15, enter:

   [shift] ERASE STANDARD 15 EXECUTE

   To erase a range of STANDARDS, number 15 to 25, enter:

   [shift] ERASE STANDARD 15 TO 25 EXECUTE

   To erase all STANDARDS, enter:

   [shift] ERASE STANDARD EXECUTE

STATUS

The STATUS key is used in four types of commands: determination of (1) instrument operating parameters, (2) data stored in memory (STANDARDS), (3) data stored on flexible disc (FILES), and (4) the relative fit of standards to calculated CONCENTRATION curves.

Status reports are automatically printed on the designated printer. The status of an entire flexible disc is an exception. This status report is listed on the CRT.

1. Operating Parameters

To print the current operating conditions, press STATUS EXECUTE. An example report is shown in Figure 4-4. To reset the instrument status to turn-on conditions, press [shift] ERASE STATUS EXECUTE.

2. Stored STANDARDS

To print a list of all standards currently in memory, press:

STATUS STANDARD EXECUTE

To print a list of a certain range of STANDARDS, press:

STATUS STANDARD n TO m EXECUTE

where n and m are between 1 and 99

To print the status of a particular STANDARD, press:

STATUS STANDARD n EXECUTE

To print the status of the data currently in the data buffer, press:

STATUS STANDARD 0 EXECUTE

3. Data Stored on Disc (FILES)

To print the contents of an extire flexible disc, enter:

STATUS FILE EXECUTE

All files and programs on the disc located in the currently designated drive are then listed on the CRT. The contents of an entire disc are listed only for the currently designated drive.

To print the status of a particular FILE, enter a command of the format:

STATUS FILE n [,m] EXECUTE

where n = file number (1 to 999999)
m = disc drive code (if not the currently designated disc drive)

The current disc is the lowest numbered disc. Alternate discs must be addressed using the parameter m. For example, to list the status of file number 150 on the current drive, enter:

STATUS FILE 150 EXECUTE

To list the status of file number 150 on drive number 701, enter:

STATUS FILE 150, 701 EXECUTE

See page 7-9 for an explanation of disc drive designations.

4. Status of CONCENTRATION Method

The HP 8451 can generate calibration curves relating absorbance to the know concentration of standards. A STATUS CONCENTRATION command can be used to report the relative fit of the experimental standards to the curve.

The operator must first enter a single wavelength (or time) value to be used in generating the calibration curve. The type of curve to be calculated (concentration methods 0 to 3) and the standards to be used are specified by entering of a command such as

CONCENTRATION 2, 7, 8, 9, 10 EXECUTE

which uses CONCENTRATION method 2 (second-order with a zero intercept), and STANDARDS 7 to 10. The following command may then be entered:

STATUS CONCENTRATION EXECUTE

See Figure 6-4 for an example report.

STOP

The STOP key is used to stop any operation which is in progress. The screen is cleared. Any OVERLAY operation is ended.

Pressing the STOP key also resets all I/O devices (plotters, printers, disc drives). For an external plotter, for example, this means that the plotter is reinitialized (the linetype, scaling points, and pen selection return to their turn-on values).

If a disc drive has been added to the HP 8451 system (or turned on) after the HP 8451 power was turned on, pressing STOP causes the HP 8451 to search for the presence of a disc drive (or other mass storage device) and to recognize its presence thereafter.

TIME SCALE

The TIME SCALE key is used to specify the x-axis range for data displayed over a time period (in seconds). The operator can select a range of time, a single time value, or a list of up to 20 time values. For example:

TIME SCALE 0 TO 60 EXECUTE

TIME SCALE 20 EXECUTE

TIME SCALE 0, 5, 10, 15 EXECUTE (up to 20 values)

To return to the full time range of the data currently in the data buffer, enter:

TIME SCALE EXECUTE

TO

The TO key is used in two different ways: (1) to specify a range of numbers, and (2) to store data in STANDARDS or FILES.

1. Range of Numbers

   The following are representative examples:

   LAMBDA 200 TO 400 EXECUTE

   STATUS STANDARD 1 TO 10 EXECUTE

   ABSORBANCE 400 TO 450 EXECUTE

2. Storing Data

   To store data in a STANDARD, use the format:

   TO STANDARD n [,c [,s]] [,"name"] EXECUTE

   where n = standard number (1 to 99)
   c = concentration value (default = 1)
   s = standard deviation of the concentration (default = 0)
   name = optional name entered with the alphanumeric keyboard

   To store data in a flexible disc file, use the format

   TO FILE n [,m] EXECUTE

   where n = file number (0 to 999999)
   m = three-digit address of disc drive (if not the currently designated drive)

TRANSMITTANCE

The TRANSMITTANCE key is used to set the data processing to transmittance. The results are then displayed in transmittance units.

The TRANSMITTANCE processing is cleared by entry of a new function (absorbance, concentration, etc.) or by the ERASE STATUS command.

Y-SCALE

The Y-SCALE key allows the operator to select a fixed scale for the vertical dimension of a plot. For example:

Y-SCALE 0 TO 1 EXECUTE

Y-SCALE -0.1 TO 0.1 EXECUTE

Y-SCALE 15 TO 25 EXECUTE

To return to automatic y-scaling, enter:

Y-SCALE EXECUTE

QUANTITATION

INTRODUCTION

It is well known that the absorbance of a material is proportional to its concentration. If the absorbance of an unknown can be determined relative to one or more standards of known concentration, the concentration of the unknown can be calculated.

Five mathematical methods for calculating concentrations are available in the Advanced Techniques Module accessory (HP 89050A). Four of these (methods 0, 1, 2, and 3) are used to quantitate a single absorbing component in a sample. Each routine develops a calibration curve based on user-entered data for one or more standards. Concentration method 4 is used for "multicomponent analysis," that is, the quantitation of several components in a mixture. This analysis is based on the absorbance characteristics of the individual pure components and a calculation of which combination of the individual spectra best accounts for the spectrum of the mixture.

Statistical Treatment

The HP 8451 can use either a maximum likelihood statistical treatment or a simple least squares method in determining the fitted curves for quantitation.

The least square method selects a calibration curve such that the sum of the squares of the distance between each data point and the curve is minimized.

The maximum likelihood method used in the HP 8451 is a weighted least squares method tailored for quantitative analysis. In this method, the variance of the data is assumed to be due only to the variance of the measurements. Chemical changes of the analyte that may occur in the sample but not in the standards (e.g., side reactions) are not taken into account. The data points used in specifying a calibration curve are statistically weighted in proportion to the inverse of their variance. The variance is automatically recorded for all measurements except for those with an integration time of 0.1 to 0.9 seconds. The maximum likelihood statistical treatment can only be used with standards that contain variance information (i.e., for those with measurements with integration times of at least one second).

At turn-on, the maximum likelihood treatment is used automatically. If desired, the operator can select the least squares treatment by executing the command

[shift] MODE 2, 1 EXECUTE

The calculations will now employ the least squares technique only.

NOTE

> An error message will result if the maximum likelihood method is attempted when any of the STANDARDS or unknowns are measured without standard deviations.

To return to the maximum likelihood treatment press

[shift] MODE 2 EXECUTE or

[shift] ERASE STATUS EXECUTE

DETERMINING CONCENTRATION OF A SINGLE COMPONENT

Summary of Procedure

Determination of a single component requires the following steps:

1. Selection of wavelength range for measurements.
2. Selection of data processing function.
3. Measurement of a standard of known concentration.
4. Storage of the standard spectrum and concentration in memory.
5. Measurement and storage of additional standards.
6. Selection of best wavelength range (if necessary).
7. Selection of best concentration method.
8. Measurement and analysis of the unknown.

Each of these steps is described in detail below.

Selecting the Wavelength Range

The HP 8451 can calculate the concentration of an unknown using any wavelength at which the sample absorbs, not just the wavelength of maximum absorbance. Moreover, a range of wavelengths or a list of up to 20 wavelength values may be used.

Initially, we suggest that the measurements of the standards be performed using all wavelengths which are of potential importance. The procedure for determining the best wavelength range is described later.

Selecting the Data Processing Function

Any data processing which results in values proportional to concentration may be used. The most common choice is the simple absorbance. The derivative of absorbance is also proportional to concentration, however, and sometimes has the advantage of eliminating spectral variations due to baseline shifts.

Biomedical applications in which turbid samples are often used, frequently employ a three-point difference in absorbance in order to compute concentration. For the sample spectrum shown in Figure 6-1, the absorbance at the maximum can be calculated relative to a constructed baseline between the minima at either side of the peak. This calculation requires that we first compute the factor F as follows:

$$F = \frac{274 - 240}{302 - 240} = 0.548$$

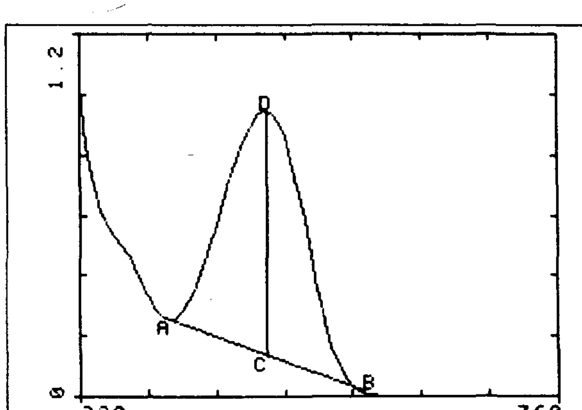
The factor is then used to enter the absorbance difference. For the example shown in Figure 6-1, the appropriate command is as follows:

ABSORBANCE 240 - ABSORBANCE 302 * 0.548 +

ABSORBANCE 274 - ABSORBANCE 240 EXECUTE

NOTE

> Extended calculations of this type are evaluated strictly left to right, not using the normal arithmetic hierarchy.



A = 240 nm
B = 302 nm
C = 274 nm

Figure 6-1. A Three-Point Absorbance Difference

Measuring and Storing Standards

Once the wavelength range and data processing function have been selected, place the first standard solution in the cell holder and press

MEASURE EXECUTE

Store the spectrum (or other result) in memory along with its concentration. If the standard deviation of the concentration is known, it can be entered as well. The command

TO STANDARD 1, 5.37, .05 EXECUTE

stores the spectrum in the location STANDARD 1 with a concentration of 5.37 and a standard deviation of 0.05 for the concentration.

Measure and store additional standards as above, entering the appropriate concentration for each. **All of the standards must use the same type of data processing and the same wavelength range.**

Selecting the Best Wavelength

If the sample was originally measured over a fairly broad wavelength range, the next step in developing the analysis method is to determine the optimum wavelength (or wavelength range) for the analysis.

This is done by treating one of the standards as if it were an unknown and calculating the concentration of the sample at all wavelengths across the range originally measured.

The procedure is as follows:

1. Set the wavelength range to the full range measured.

2. Recall the standard which is to be used as the unknown. Use of the most concentrated standard is recommended since it will be most likely to show any deviation from linearity.

   RECALL STANDARD 5 EXECUTE

3. Enter as data processing one of the concentration methods (0 to 3), referring to the appropriate standards. To use concentration method 0 and standards 1 to 5, enter

   CONCENTRATION 0, 1, 2, 3, 4, 5 EXECUTE

4. Calculate and plot the results by pressing

   PLOTTER EXECUTE

The resulting plot shows the calculated concentration as a function of the wavelength used to calculate the concentration. Figure 6-2 shows an example. In this case, the standard actually had a known concentration of 20, and the plot shows that the region around 500 nm gives the correct result.

To test one of the other concentration methods, simply enter the concentration command specifying a new concentration method (number 3 in this case),

CONCENTRATION 3, 1, 2, 3, 4, 5 EXECUTE

Then calculate and plot the new result by pressing

PLOTTER EXECUTE

Observe the resulting plots and select the wavelength to be used in the analysis. You may select any of the following:

1. a single wavelength value
2. a single wavelength range
3. a list of up to 20 individual wavelength values

Using more than one wavelength has the advantage of averaging the results and thus improving precision.

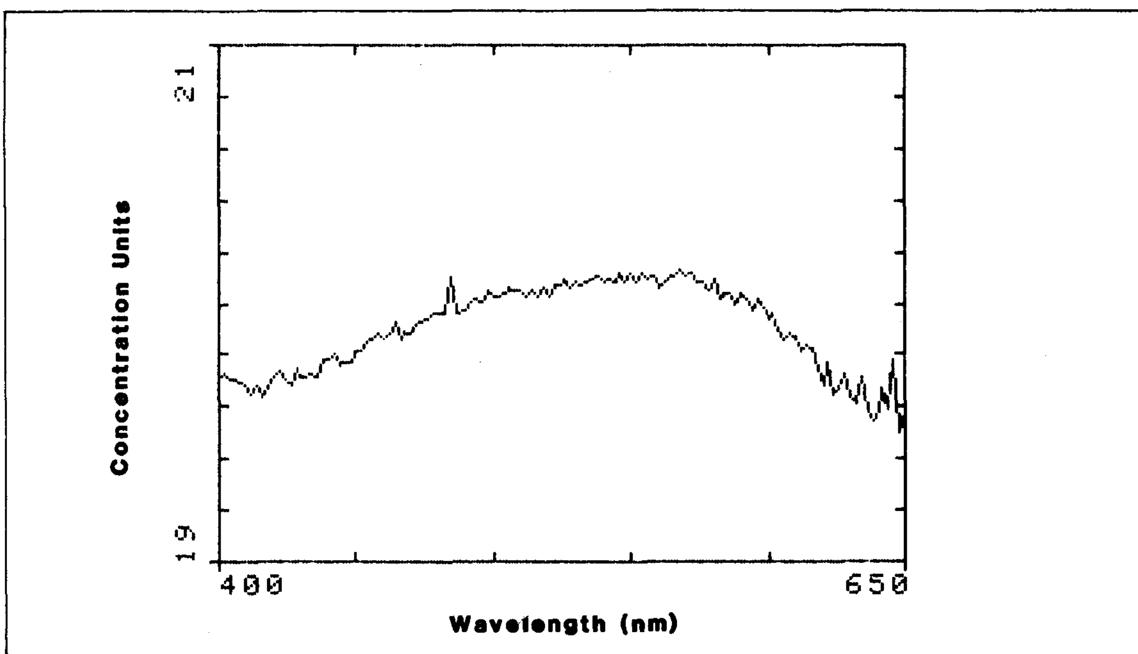


Figure 6-2. Calculation of Concentration Using a Range of Wavelengths

Selecting the Concentration Method

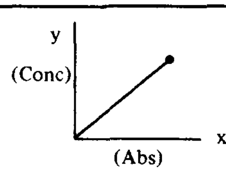
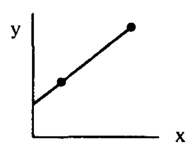
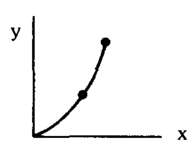
There are four concentration methods for determination of a single component available in the HP 8451. Each employs a calibration curve based

on the measured standards. The type of calibration curve may be any of the following:

Method 0: linear, intercept through zero
Method 1: linear, non-zero intercept
Method 2: second order, intercept through zero
Method 3: second order, non-zero intercept

The four methods are illustrated along with the minimum number of standards required in Figure 6-3.

The technique for testing which concentration method best fits the standards uses the STATUS CONCENTRATION command. This command calculates how closely each of the standards falls to the calibration curve and also reports the constants k0, k1, and k2 used to define the curve (see Figure 6-3).

Concentration Routine (N)	Calibration Curves (Minimum Number of STANDARDS Shown)	Relationship Used in Calculation	Number of Standards Possible
0		$y = K_1 x$	1 to 12
1		$y = K_0 + K_1 x$	2 to 12
2		$y = K_1 x + K_2 x^2$	2 to 12
3		$y = K_0 + K_1 x + K_2 x^2$	3 to 12

x = the measured value stored in the STANDARD, usually ABSORBANCE data.

y = the concentration value entered from the keyboard when the STANDARD was created.

K_0, K_1, K_2 = constants determined for a particular calibration curve. K_0 = intercept, K_1 = slope , K_2 = curvature

Figure 6-3. Concentration Methods for the Analysis Of A Single Component

A STATUS CONCENTRATION calculation requires that only a single value from each STANDARD be used. A single wavelength (or time value) or average absorbance over a wavelength range is selected prior to executing the STATUS command. Consider as an example, the case in which four STANDARDS (6 to 9) have been created. Each STANDARD contains the measured absorbance at 400 to 800 nm of a solution with a known sample concentration. The operator must first select the wavelength value to be used. This value is specified by entering, for example, LAMBDA 572 EXECUTE.

The operator then selects concentration method 0 and standards 6 to 9 by entering:

CONCENTRATION 0, 6, 7, 8, 9 EXECUTE

and the status report is generated by pressing

STATUS CONCENTRATION EXECUTE

The resulting report is shown in Figure 6-4. The value K0, K1, and K2 are the calculated coefficients for the calibration curve (see Figure 6-3). The report then lists each standard used in calculating the curve, its absorbance at LAMBDA 572 (the single measured value which was previously selected), and its known concentration (as entered during the creation of the standard). The % ERROR column shows a measure of how far each of the calibration points deviates from the calculated best fit curve. The error is calculated from the equation

$$\text{Error} = \frac{Y - (K_0 + K_1 X + K_2 X^2)}{K_0 + K_1 X + K_2 X^2} * 100$$

```
     STATUS CONCENTRATION 0
   K0= 0
   K1= 94 7555
   K2= 0
STD    ABS          CONC         % ERR
6     .105247       10               .3
7     .210494       20               .3
8     .318898       30             -.7
9     .421198       40               .2
```

Figure 6-4. Example STATUS CONCENTRATION Report

where K0, K1, K2, X and Y are as defined in Figure 6-3. The term K0 + K1(X) + K2(X)2 represents the concentration calculated from the calibration curve whereas Y is the true concentration entered from the keyboard.

To test a second concentration method (number 1, for example), enter the revised concentration command as follows:

CONCENTRATION 1, 6, 7, 8, 9 EXECUTE

Then press

STATUS CONCENTRATION EXECUTE

Notice that the error calculation is only meaningful when more than the minimum number of standards are used to generate the calibration curve. When the minimum number of standards is selected, the calculated curve must pass through each point. In such cases the STATUS CONCENTRATION report indicates that no meaningful error calculation can be made by showing an asterisk in the % ERROR column.

The STATUS CONCENTRATION command may be used for a range of wavelengths by creating STANDARDS which contain the average absorbance over the range. For example, suppose the concentration was to be calculated using data over the wavelength range 560 to 580 nm. The operator simply takes the average of the data in each STANDARD (6 to 9, for example) and stores it in a new STANDARD (16 to 19, for example). The commands are as follows:

RECALL STANDARD 6 EXECUTE

ABSORBANCE 560 TO 580 EXECUTE

PRINTER EXECUTE

TO STANDARD 16 EXECUTE

If the standards 7 to 9 are treated similarly, the operator can then perform the STATUS CONCENTRATION calculations specifying standards 16 to 19. The resulting calculations then use the average of the absorbance over the specified range.

Analyzing the Unknown

When the wavelength (range), type of data processing, and concentration method have been selected, you are ready to measure and analyze the unknown sample. Place the unknown sample in position and press MEASURE EXECUTE. The calculated result is printed on the current designated printer. For example,

500 = 6.02

That is, using the absorbance at 500 nm, the calculated sample concentration is 6.02 mg/L (or other unit used for the standard).

MULTICOMPONENT ANALYSIS

When more than one component is present in a sample, we refer to it as a multicomponent mixture. "Multicomponent analysis" is a technique which attempts to determine the concentration of various components in a mixture without prior separation. This is possible providing the individual components have characteristic absorption spectra which are not identical. A spectrum for every component which absorbs in the wavelength range to be used is measured and stored in memory as a STANDARD. The goal, then, is to mathematically determine what combination of the various components best accounts for the measured spectrum of the mixture.

The HP 8451 determines what percentage of each spectrum, which has been specified as a standard for the analysis, must be added together to produce a spectrum which matches as closely as possible the spectrum measured for the mixture.

Procedure for Multicomponent Analysis

The steps required for the analysis of a three-component mixture are as follows:

1. Select the data processing to be used for the samples. Absorbance is used most commonly.

   ABSORBANCE EXECUTE

2. Select the wavelength range to be used. It is desirable to store all wavelengths at which <u>any</u> of the components absorb at first until an optimum range is determined. For the visible region, press

   LAMBDA 400 TO 820 EXECUTE

3. Measure the spectrum of a solution containing a known concentration of the first component in the mixture.

   MEASURE EXECUTE

4. Store the measured spectrum in memory along with its known concentration. To store the spectrum in STANDARD 10 with a concentration value of 2.57 and a standard deviation for the concentration of 0.05, press

   TO STANDARD 10, 2.57, .05 EXECUTE

5. Measure and store spectra of each of the other pure components, entering their concentrations as in step 4.

6. Enter the multicomponent data processing (concentration method 4) referencing the three stored STANDARDS (for example, 10 to 12):

   CONCENTRATION 4, 10, 11, 12 EXECUTE

7. Measure the spectrum of the mixture and calculate the relative concentrations of the various components:

   MEASURE EXECUTE

8. An example multicomponent analysis report is shown in Figure 6-5. In practice, the operator should limit the wavelength range to the region in which the various components exhibit spectral differences. To recalculate the result over a different wavelength range, enter the range (or a list of up to 20 wavelength values), for example

   LAMBDA 500, 502, 504, 510, 512, 600, 602 EXECUTE

   Then recalculate the results by pressing

   PRINTER EXECUTE

```
    multicomponent analysis
relative fit error     123.282
independence of stds   4.83056
STD     CONC           std dev
1        20.5719       .0064
2        10.0681       .0092
3        31.5528       .0071
```

Figure 6-5. Example Multicomponent Analysis Report

Additional information for statistical results of quantitative analysis reports is given in Section 8, Basic Programming (see page 8-17).

Guidelines for Multicomponent Analysis

The procedure described above for performing multicomponent analysis is a highly simplified illustration intended as a summary of the essential steps involved. In practice, the development of a multicomponent analysis requires careful consideration of many experimental parameters. The following guidelines are offered as suggestions.

1. Beer's law must be obeyed over the concentration range of the analysis for each component and for the mixture. That is, absorbances are considered additive within the linear range of the instrument. For best results, operate with standards in the range of 0.1 to 1.0 absorbance

units. Good results may generally be obtained from data in the range from 0.01 to 2.0 absorbance units.

2. Spectra for all components in the mixture which contribute to absorbance within the analytical wavelength region must be used as standards for the analysis. The spectrum for each component, when measured as the pure compound, must be identical to the spectrum observed for that compound in the mixture being analyzed. That is, side reactions are not accounted for, except in the indication of quality of fit.

3. Although considerable spectral overlap and similarity of the shapes of spectral curves among the components can be tolerated, there are limits beyond which results become extremely sensitive to noise and resolution of the components becomes unreliable. All other parameters being constant, accuracy and precision increase with decreased spectral overlap and similarity.

4. A REFERENCE measurement should be made prior to analysis. For liquid samples, a solvent-filled cuvette (or flow cell) must be used during the reference measurement.

5. Use only the wavelength range of interest in the calculation. Additional wavelengths, if they do not add to spectral uniqueness, increase the noise level of measurements and extend the required calculation time.

6. Analyze synthetic mixtures of the components in question covering the analytical limits expected to be encountered with unknowns. This will establish typical values for the parameters, Independence of Standards, Relative Fit Error and Relative Standard Deviation as they relate to the accuracy and precision of analyses of the chemical system in question. Significant changes in these parameters during the routine analyses for unknowns are indications of a change in the measurement system or chemical system such as a technician error, an extraneous component in the mixture, deterioration in the signal-to-noise ratio in the measurements, etc. Since these values are very dependent upon the analytical spectrum, all inclusive rules-of-thumb for analysis are difficult to estimate.

7. High optical quality (quartz or glass) cells must be used; plastic cells are not recommended.

8. Best results are usually obtained with a flow cell. The next best choice is to use the same cell for all standards and unknowns. If it is necessary to use separate cells for standards and/or unknowns, they should be sufficiently matched to ensure that no spectral distortion is introduced by any of the cells since a reference measurement for each of the cells is not the correction of choice.

9. In certain cases, it may be beneficial to include a "noise" or "baseline" spectra as one of the standards. Such a spectrum is obtained by using the following commands:

ABSORBANCE - ABSORBANCE + 0.1 EXECUTE

MEASURE EXECUTE

TO STANDARD n EXECUTE

The first command arbitrarily adds 0.1 to every data point in a null spectra (ABSORBANCE - ABSORBANCE). The result is representative of noise from a measurement, and it is stored in STANDARD n with an arbitrary concentration (default concentration = 1). For example, the CONCENTRATION command for a three component analysis is:

CONCENTRATION 4, 10, 11, 12, 13 EXECUTE

where the analytical standards are stored in locations 10, 11 and 12 and the "noise" standard is in location 13. After a sample unknown is measured, a computed concentration will be assigned to STD 13. This computed concentration is of no analytical use. It was included in the CONCENTRATION command so that the final results include a contribution from the measurement noise.

Error Analysis

An indication of the degree of accuracy of the multicomponent calculations of concentration can be obtained by careful consideration of three parameters: (1) relative fit error, (2) independence of standards, and (3) relative standard deviation of each component.

Relative Fit Error

For the HP 8451 the relative fit error is related to the chi-squared value of the spectral or time-based data fitted with the standards designated. The multicomponent calculations minimize chi-squared by using a maximum likelihood algorithm. The relative fit error is an indication of how well the algorithm was able to fit the data, and is normalized with respect to the noise of the measurement of the standards and the unknown.

The expected average value of the relative fit error for repeated measurements equals one. A number close to one means that the ratio of the actual error (between the measurement and the standards) and the expected error due to statistical variation (as indicated by the prior measurements of the standards and of the unknown) is close to one. In practice, this number is highly dependent on the type of measurements being made, the accuracy of those measurements, and whether unaccounted impurities or chemical interactions are present.

Independence of Standards

For the HP 8451 calculations, the independence of standards is their covariance. High values indicate high spectral similarity between components. As the standards become less and less unique, the multicomponent algorithm has greater difficulty distinguishing between them. This can lead to errors in quantitation of the species involved.

Optimally, the independence of standards value should be on the same order of magnitude as the standard deviation of the measurements. The value calculated for the independence of standards increases as the spectral overlap of the standards increases. Experimentally, the independence of standards value is optimized (lower) when the absorbance range values of the standards are similar. For example, all standards in the range of 0.5 au will result in a lower value for the independence of standards (as well as more accurate results) than one standard in the 0.01 au range and another in the 2 au range. As components are added to a series, the independence of standards should be monitored. If there is a significant increase with the addition of a standard, the calculated values should be carefully checked against expected results.

Relative Standard Deviation

For a multicomponent analysis, the relative standard deviation may be defined as the concentration normalized standard deviation.

$$\text{relative standard deviation} = \frac{\text{standard deviation}}{\text{concentration}}$$

The benefit of using relative standard deviation is illustrated in a case where identical standard deviations are compared to different concentration standards. For a standard deviation of 0.1, the relative standard deviation is 0.01 for a standard concentration of 10 units and 0.50 for a standard concentration of 0.2 units. In general, the confidence level in a multicomponent analysis is greatest when the relative standard deviation is minimized.

In the development of a multicomponent analytical method, the value for the relative standard deviation should be calculated and used as a measure of statistical confidence. In some cases, where measurement or concentration uncertainty of standards is quite large, the relative fit error can be low. This indicates that the multicomponent algorithm can not adequately distinguish between the measurement uncertainties of the unknown and those of the standards. The relationship between relative standard deviation and other HP 8451 operational considerations is shown in Figure 6-6.

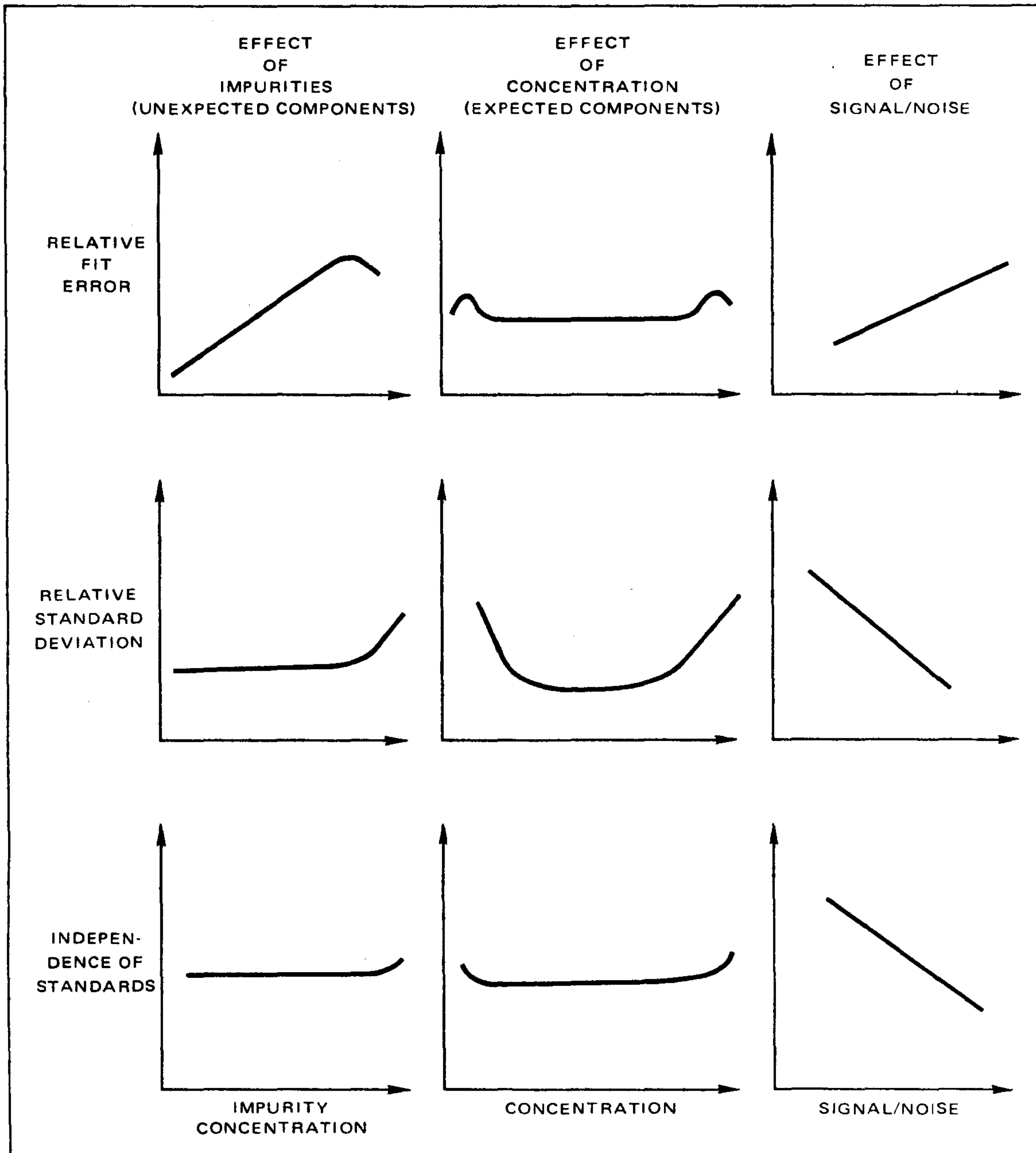


Figure 6-6. Multicomponent Analysis Operational Considerations

Section 7

ACCESSORIES

INTRODUCTION

The HP 8451 is designed to be interfaceable to a wide variety of peripheral devices, including plotters, printers and disc drives. This section describes the proper use of these devices.

> **NOTE**
>
> Refer to Section 3, Installation, for the proper installation of plotters, printers and disc drives.

A description of the sipper and autosampler accessories, the thermostattable cell holder, and the adjustable cell holder are also included.

PLOTTERS

When large format, high quality plots are required, an external plotter can be used with the HP 8451. Such an accessory requires the HP-IB Interface and a ROM Drawer containing a plotter/printer ROM to be installed in the HP 8451.

Any HP plotter which uses HP-IB and the HP Graphics Language (HPGL) can be used for external plotting. Three plotters are particularly recommended:

1. HP 7470A Graphics Plotter

   This two-pen plotter uses 8-1/2" x 11" paper. A micro-grip drive moves the paper in the x-direction while the pen moves in the y-direction, resulting in high speed plotting.

2. HP 7475A Graphics Plotter

   A six-pen carousel plotter that uses either 8-1/2" x 11" or 11" x 17" paper. The plotter operation is similar to the HP 7470A.

3. HP 9872T XY Plotter

   A versatile eight-pen plotter that uses either 8-1/2" x 11" or 11" x 17" paper, and also can use a continuous roll of plotter paper. Paper can be automatically advanced and cut by a built-in paper cutter, thus allowing complete automation of external plotting.

Designating an External Plotter

At turn-on, the HP 8451 uses the CRT as its current plotter. That means that all results output by a PLOTTER EXECUTE or MEASURE EXECUTE command are plotted on the CRT. In order to plot results on an external plotter, the operator must first designate the external plotter by entering a command such as

PLOTTER n EXECUTE

where n is a three-digit number representing the plotter address.

The first digit is the interface select code (3 to 9). Plotters are almost always interfaced via HP-IB using the factory set select code, 7. The last two digits of the numeric parameter are the HP-IB address of the plotter. The HP-IB address is user-selectable from 0 to 31, and is set on the plotter by a binary code. The factory set HP-IB address for plotters is 05. (If necessary, refer to the operator's manual for the plotter in order to set this address on the plotter.) To designate plotting on an HP-IB plotter using interface select code 7 and HP-IB address 05, enter:

PLOTTER 705 EXECUTE

Once the plotter has been so designated, all plots are performed on that device until explicitly changed by the operator. Entering a PLOTTER command as above also designates that plotter as the output device for measurements. (See page 4-10 for further information.)

Plotter Operation

After designating the external plotter for output (see above), data is plotted by simply entering

PLOTTER EXECUTE

Note that the x- and y-axes are not automatically added, but must be specified by entering

[shift] AXIS EXECUTE

This step is performed separately in order to allow for several plots to be overlaid on a single sheet, and to allow a pen color change for the axes if desired. Note that when overlaying plots, a fixed Y-scale should be used. The ranges for the axes are those currently in the instrument status report.

Annotation

Plots may be annotated in any of several ways. First, up to 20 x-values (wavelengths or times) of particular interest may be labelled automatically with their y-values. To label a plot at 300, 350, and 400 nm, first enter

[shift] ANNOTATION 300, 350, 400 EXECUTE

When the plot is drawn, these three points are automatically labelled. Figure 7-1 shows an example.

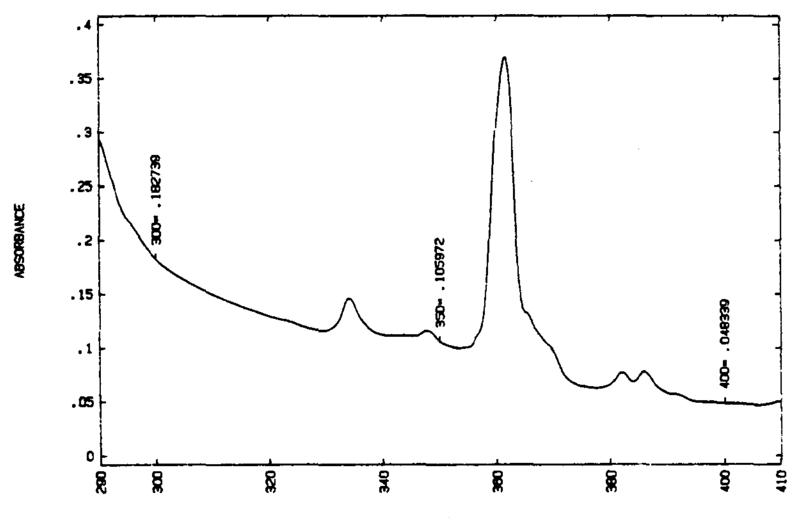


Figure 7-1. Annotated Plot

Once such an ANNOTATION command has been entered, it remains in effect for all further plots. The ANNOTATION is cancelled by entering

[shift] ANNOTATION EXECUTE

by redesignating the current plotter, or by entering ERASE STATUS.

A second type of annotation may be performed by specifying PEAK FIND data processing. When a PEAK FIND command has been entered as part of the data processing, the output to an external plotter is automatically labelled at the peaks which exceed the PEAK FIND threshold. (See page 5-16 for further information on the PEAK FIND algorithm.) An example plot annotated by PEAK FIND processing is shown in Figure 7-2.

Finally, the operator can annotate plots in just about any way desired using the HPGL command "LABEL" to label plots. See page 7-5.

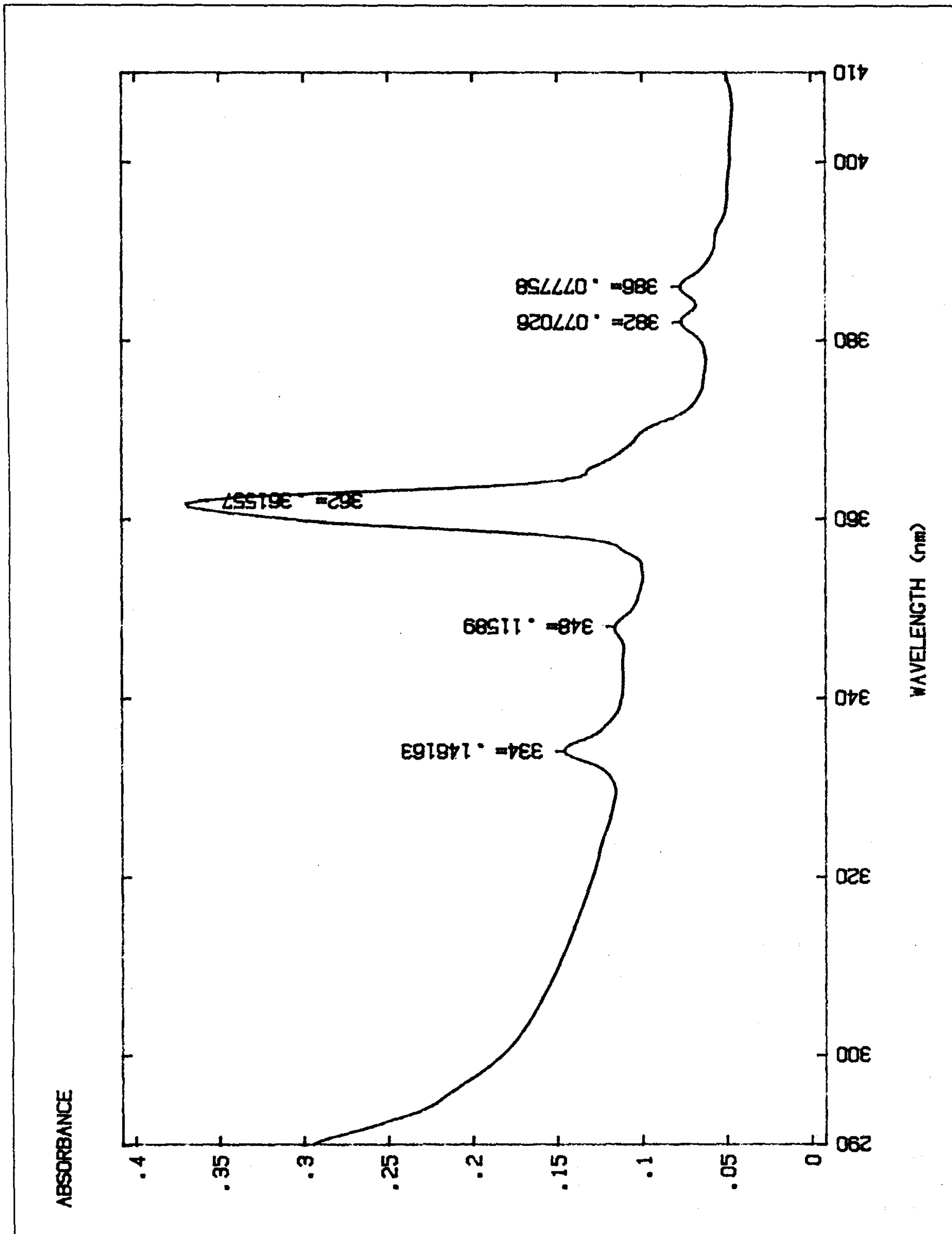


Figure 7-2. Plot Annotated with PEAK FIND Data Processing

Interpolation

The operator can select the type of interpolation to be used in plotting the curve between adjacent data points. At turn-on, a smooth curve interpolation is used.

To select straight line interpolation between data points, press

[shift] INTERPOLATE 1 EXECUTE

Straight line interpolation is faster, and for broad peaks is only slightly different in appearance.

To return to smooth line interpolation, enter

[shift] INTERPOLATE 0 EXECUTE

or [shift] ERASE STATUS EXECUTE

The latter command resets the instrument to turn-on conditions.

Selection of Linetype

Any of eight different styles of linetype can be selected for external plots. The operator can also select the length of the repeat pattern. Figure 7-3 shows the various linetypes.

The linetype is entered by a command of the format

[shift] LINETYPE n [, l] EXECUTE

where n is the style of line 1 to 8 (default = 1) and l is the repeat length (default = 4).

HPGL Commands

If the optional alphanumeric keyboard is present, the plotters recommended for use with the HP 8451 may also be addressed in HPGL (Hewlett-Packard Graphics Language). The HPGL commands provide a wide variety of plotting and printing functions including labelling in various sizes of print, moving the pen to specified locations, selecting a new pen color, etc. A few of the most useful commands include the following:

LABEL: used for printing and for labeling plots

DEG: used to put plotter coordinates in degrees mode

MOVE: used to move pen to desired position

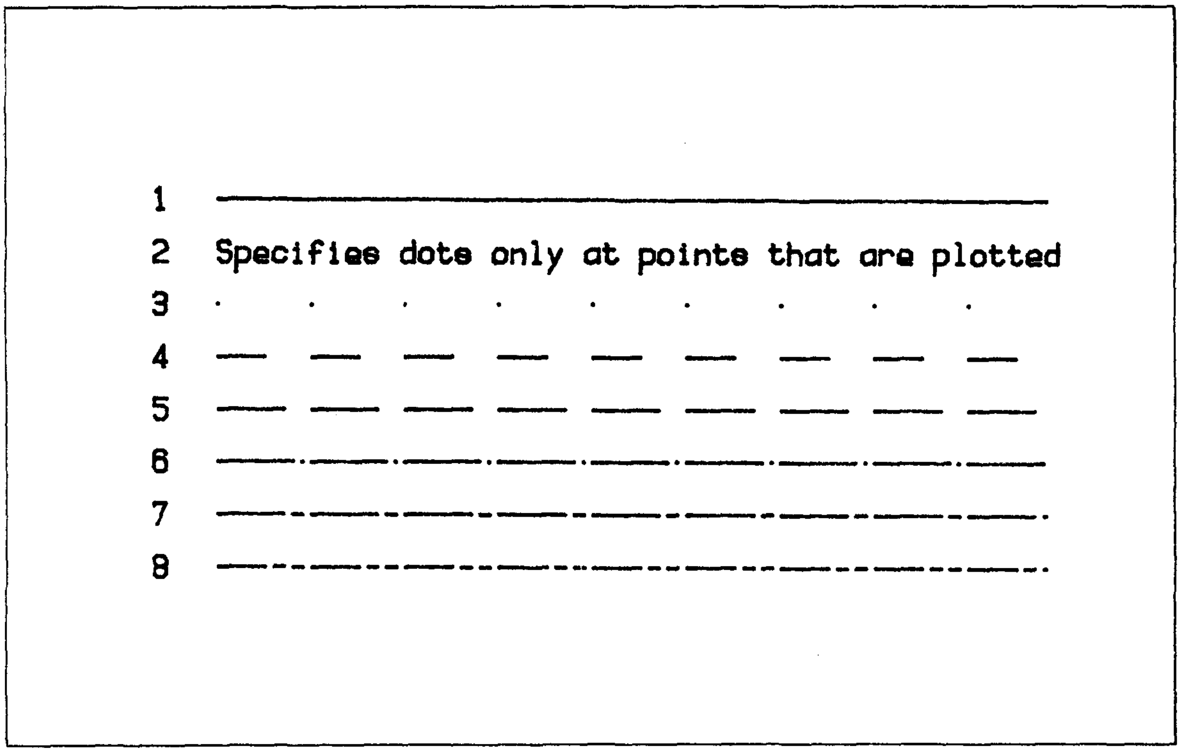


Figure 7-3. Linetypes (with Default Repeat Length)

LDIR 0: specifies printing horizontal to x-axis

LDIR 90: specifies printing vertical to x-axis

PEN 1: selects left pen

PEN 2: selects right pen

PEN 0: puts all pens back

Refer to the Plotter Operator's Manual for a complete description of HPGL commands.

PRINTERS

External printers may be interfaced to the HP 8451 via either HP-IB or RS-232. An HP-IB Printer requires the HP-IB Interface and a ROM Drawer containing a plotter/printer ROM to be installed in the HP 8451. An RS-232 printer requires the Serial Interface Module and the ROM Drawer and plotter/printer ROM. Most HP-IB printers may be used. The HP 82905B Printer is recommended.

Designating an External Printer

At turn-on, the HP 8451 uses the built-in printer as its current printer. That means that all results output by a PRINTER EXECUTE command and all STATUS reports are printed on the built-in printer. In order to print results on an external printer, the operator must first designate the external printer by entering a command such as

PRINTER n EXECUTE

where n is a three-digit number representing the printer address.

The first digit is the interface select code (3 to 9). Printers are usually interfaced via HP-IB using the factory set select code, 7. The last two digits of the numeric parameter are the HP-IB address of the printer. This address is user-selectable from 0 to 31, and is set on the printer by a binary code. The factory set HP-IB address for printers is 01. (If necessary, refer to the operator's manual for the printer in order to set this address on the printer.) To designate plotting on an HP-IB printer using interface select code 7 and and HP-IB address 01, enter

PRINTER 701 EXECUTE

For printing on an external printer which is interfaced via RS-232, n is 10. To designate such a printer, enter

PRINTER 10 EXECUTE

Once the printer has been designated as above, all printed reports are sent to that device until it is explicitly changed by the operator. Entering a PRINTER command such as those above below also designates that printer as the output device for measurements. The command [shift] ERASE STATUS EXECUTE resets the plotter to its default, the built-in printer.

Printer Operation

After designating the external printer as above, the command

PRINTER EXECUTE

causes the data currently in memory (STANDARD 0) to be processed according to the current entries in the instrument status, and the results to be output to the currently designated printer.

The data processing includes the display limits, the function processing (absorbance, transmittance, etc.) and CONCENTRATION or PEAK FIND processing, if any.

DISC DRIVES

When permanent storage of data is required, a peripheral disc drive can be used. Such an accessory requires the HP-IB Interface and a ROM Drawer containing a mass storage ROM installed in the HP 8451.

Three types of disc drive systems are recommended for use with the HP 8451 Spectrophotometer. Each type of drive is available in either a single drive or a dual drive configuration. The characteristics of the various drives are summarized in Table 7-1.

TABLE 7-1. FLEXIBLE DISC DRIVE MODELS

Model	Drive Type	Disc Size	Storage Capacity (Kbytes)
HP 9121S	Single Flexible Disc Drive	3-1/2"	270
HP 9121D	Dual Flexible Disc Drive	3-1/2"	540
HP 82902M	Single Flexible Disc Drive	5-1/4"	270
HP 82901M	Dual Flexible Disc Drive	5-1/4"	540
HP 9134A	Winchester Fixed Disc	5-1/4"	6380
HP 9133A	Winchester Fixed Disc with 3-1/2" Flexible Disc Drive	5-1/4"	6660
HP 9135A	Winchester Fixed Disc with 5-1/4" Flexible Disc Drive	5-1/4"	6660

Disc "Write Protection"

Flexible discs can be "write protected" to prevent erasure or overwriting of important files. Refer to the appropriate operators manual for the mechanism for write protecting your discs.

Formatting a New Disc

A new disc must be formatted before use the with the HP 8451. To format a disc, place the disc (not write protected) in drive 0. Enter the command

[shift] ERASE FILE - 1 EXECUTE

This keystroke sequence initiates the format procedure for the entire disc. All information is removed from the disc. During the formatting of the disc, it is also tested for possible defects. If defects in the disc are discovered, the error message ERROR 129: MEDIUM is displayed. If this message occurs, retry the format procedure a few times. If the disc cannot be formatted after a few tries, the disc is defective and should be discarded.

Care of Flexible Discs

Flexible discs are delicate and must be handled **carefully.** Disc damage can result in lost data and programs. Never touch the surface of a disc nor bend or fold the disc. Use a soft felt tip pen to label the disc, never a ballpoint pen. Note that although the discs provide several million revolutions (about 50 hours) of service, they do eventually wear out. The user must make backup copies of important data, as this is the only sure protection against loss. Refer to the disc drive Operator's Manual for additional information on disc care.

Disc Drive Capacity

The storage capacity of the various disc drive models is indicated in Table 7-1. Each recorded FILE on the disc requires 104 bytes for its "header" information, plus eight bytes for each data point. Disc space required by programs cannot be calculated directly, but is shown in a STATUS FILE list.

Designating the Current Disc Drive

At turn-on, the HP 8451 locates an interfaced disc drive (or mass storage device) by searching the appropriate disc drive address codes. Power to the disc drive must be ON in order for the drive to be recognized.

The active drive found with the lowest disc drive code is automatically assigned as the "current" disc drive. The current disc is then used for all data storage and recall unless the operator explicitly specifies an alternate drive in the keyboard command.

If a disc drive is added to the system after turn-on, the operator can cause the HP 8451 to locate the new device by pressing the STOP key. This key resets all I/O devices and causes the HP 8451 to search for and locate an interfaced disc drive. The ERASE STATUS command does <u>not</u> reset the disc drive designation.

The operator can reassign the current disc drive using the optional alphanumeric keyboard. To select drive 1 at address 0, the appropriate command is as follows:

MASS STORAGE IS ":D701" END LINE

The disc drive address code is a three-digit number. The first digit is the interface select code (7 for HP-IB), the second digit is the controller address (0 to 7), and the third digit is the drive number (0 to 3).

Single Drive Systems

In a system in which only one drive is present, drive codes need not be specified. Since there is only one drive, only the file number is required.

Dual Flexible Disc Systems

A dual flexible disc system typically uses the HP-IB interface select code of 7 (factory preset value) and an HP-IB address of zero. The address code for drive 0 is then 700, and for drive 1 is 701. Drive 0 will be the "current" drive at turn-on, or when STOP is entered.

Winchester and Flexible Disc Systems

The HP 9133A and HP 9135A Disc Drive are dual disc systems comprised of a fixed hard disc drive (the Winchester) and a separate flexible disc drive. The fixed disc drive and the flexible disc drive each have their own HP-IB addresses which must be set on the rear panel. Typically, the fixed disc is given HP-IB address 0 and the flexible disc is given HP-IB address 1.

The storage capacity of the fixed disc is four times as great as that of the flexible disc. To facilitate copying portions of the fixed disc to the removable flexible disc, the fixed disc is divided internally into four areas. The four disc areas are then treated as "drives" 0, 1, 2, and 3. Assuming an HP-IB interface select code of 7 and an HP-IB address for the fixed disc of zero, the drive codes of the four areas of the fixed disc are 700, 701, 702, and 703.

The flexible disc drive is always drive 0. Assuming an HP-IB interface select code of 7 and an HP-IB address for the flexible disc drive of 1, the drive code for the flexible disc is then 710.

Listing Disc Contents

The operator can generate a list of the contents of an entire disc by placing the disc in the current disc drive and entering

STATUS FILE EXECUTE

A list of all files and programs is then printed on the CRT.

An example of such a list is shown in Figure 7-4.

Each line of the directory output describes an entry in the following manner:

NAME	The name given to the file when the program or data was stored.
TYPE	The contents of the file, program (PROG), data, null or binary program (BPGM).
BYTES	The number of bytes per record.
RECS	The number of defined records in the entry. A record is the smallest addressable unit on the disc.

```
CAT
Volume:
Name         Type  Bytes   Recs
PGM 2        PROG    256     19
PGM 1        PROG    256     44
PGM 3        PROG    256     14
PGM 4        PROG    256     54
FILE9        DATA    755      1
FILE10       DATA    675      1
FILE11       DATA    675      1
FILE12       DATA    675      1
FILE13       DATA    675      1
FILE14       DATA    675      1
RATEMETH#1   PROG    256     23
MEASRATE#1   PROG    256     33
RATEDEMO#1   DATA   2500      1
```

Figure 7-4. Disc Contents Listing

Erasing Discs

Disc drive files are erased either one at a time or an entire disc at once.

MEMORY MODULES

The standard memory size of the HP 8451 includes approximately 8000 bytes for storage of data and programs. The 16K and 128K Memory Modules accessories are available to expand the instrument storage capacity. The 16K Memory Module is used exactly as the standard memory area, while the 128K Memory Module is accessed using the alphanumeric keyboard. Size and speed of information transfer for the various memory alternatives are summarized in Table 7-2. Representative disc drives are included in the table for comparison. While the internal memory areas have the advantage of rapid access, they are not permanent storage areas, since a power failure results in loss of all stored information.

16K Memory Module

The 16K Memory Module accessory (HP 82903A) provides additional internal memory for storage of STANDARDS and BASIC programs (one program at any one time). Only one 16K Memory Module may be used with the HP 8451. The presence of this module is recognized when power is turned on to the instrument. The 16K Memory Module is accessed by the usual keyboard commands for the standard memory area. No special commands are required.

128K Memory Module

The 128K Memory Module accessory (HP 82909A) is used for data storage only. Up to three such modules may be installed in the HP 8451A. The presence of this module (or modules) is recognized when power is turned on to the instrument. The 128K Memory Module is accessed using the optional alphanumeric keyboard by specifying MEMORY commands. The Advanced Techniques Module (HP 89050A) is required for such commands.

Data is transferred from the current data buffer (STANDARD 0) to the 128K Memory Module by a command such as

TO MEMORY n EXECUTE

where n is a number from 0 to 4999.

The maximum user-selected n defines the size of the memory directory. This directory contains the address of memory locations for stored data files. The commands

```
TO MEMORY 8    EXECUTE
TO MEMORY 9    EXECUTE
TO MEMORY 10   EXECUTE
```

transfer data to three different blocks of memory and establish a memory directory with room for 11 entries even if n = 0,1,2...7 were not used. Data can be stored to any memory location in any order, but best utilization of the memory space is achieved by using the locations in ascending numerical order beginning with n = 0. The files are actually stored in memory storage sequence and not in numeric sequence. In the example above, if location n = 8 were deleted, a memory packing operation would automatically occur. Since this operation requires a finite amount of time, memory locations should be deleted in the reverse order of the storage sequence if speed is critical. If the last location stored is erased, no packing operation is initiated.

Data stored in the 128K Memory Module is not available for immediate use in CONCENTRATION commands or in extended calculations, but must first be transferred to a STANDARD.

TABLE 7-2. MEMORY ALTERNATIVE SPEED AND CAPACITY

Storage Medium	No. of Data Points Measurement	Minimum Transfer Time per Measurement (sec)		Approximate Capacity (No. of Measurements)	
		Header	No Header	Header	No Header
Standard Memory					
	316 (190-820)	0.7	N/A	2	N/A
	106 (190-400)	0.4	N/A	7	N/A
(Standards Storage	20	0.1	N/A	26	N/A
and Programs)	4	0.1	N/A	50	N/A
16 k Module	316	0.7	N/A	6	N/A
(Standards Storage	106	0.4	N/A	16	N/A
and Programs)	20	0.1	N/A	60	N/A
	4	0.1	N/A	99(1)	N/A
				(1) 99 standards maximum	
128 k Module					
(Data Storage	316	0.7	N/A	49(2)	N/A
Only)	106	0.4	N/A	136(2)	N/A
	20	0.1	N/A	486(2)	N/A
	4	0.1	N/A	929(2)	N/A
				(2) times 3 for up to 3 modules	
9121 S/D					
3-1/2" Microdisc	316	9.1	12.9	108(3)	113(3)
(286 kb capacity)	106	4.1	4.3	301(3)	338(3)
	20	2.1	0.8	1086(3)	1792(3)
	4	1.6	0.1	2108(3)	8960(3)
				(3) times 2 for dual disc	
82901/2					
5-1/4" Minidisc	316	10.3	14.8	108(3)	113(3)
(286 kb capacity)	106	4.8	5.1	301(3)	338(3)
	20	2.5	1.1	1086(3)	1792(3)
	4	2.1	0.3	2108(3)	8960(3)
				(3) times 2 for dual disc	
9133/4/5					
5-1/4" Single	316	5.9	11.5	1747	1819
Hard Disc	106	2.5	3.8	4831	5424
(4.6 Mb Capacity)	20	1.2	0.7	17424	28750
	4	0.9	0.1	33823	143750

Data is returned from MEMORY to STANDARD 0 by a command such as

RECALL MEMORY n EXECUTE

The chief advantage of the 128K Memory Module is that a relatively large amount of data can be stored very rapidly. The other alternatives for large data storage (disc drives and external computers) require much more time for data transfer.

Two special STATUS commands are used with the 128K Memory Modules. To determine how much memory space is available, enter

STATUS MEMORY (0) EXECUTE

The number of bytes currently available is then reported. To test the operation of the 128K Memory Module, enter

STATUS MEMORY (1) EXECUTE

If the memory is operating properly, the value "zero" is reported. Testing the memory in this manner does not erase it.

Memory areas must be erased prior to writing over previously stored information. Data is erased from MEMORY either one location at a time or the entire MEMORY module at once. To erase a particular MEMORY location, enter

[shift] ERASE MEMORY n EXECUTE

To erase the entire MEMORY area, enter

[shift] ERASE MEMORY - 1 EXECUTE

SIPPER/SAMPLER SYSTEMS

This section describes the set-up of the sipper/sampler systems which may be used with the HP 8451. Three levels of automation may be achieved:

1. Manual Sipper System

   Employs a manually operated peristaltic pump to pump samples into a flow cell for measurement.

2. Automatic Sipper System

   Employs a peristaltic pump which is under control of the HP 8451. Pumps samples into a flow cell for measurement. Pump may be reversed to return the sample to its container.

3. Automatic Sipper/Sampler System

   This fully automated system includes an HP 89072 Autosampler and a peristaltic pump, both under control of the HP 8451.

The components required for each of these systems are listed in Table 7-3. The set-up for each of these systems is described below, beginning with the basic manual sipper system.

TABLE 7-3. SIPPER/SAMPLER SYSTEM COMPONENTS

Item	Required for:		
	Manual Sipper	Auto Sipper	Auto Sipper/ Sampler
Flow Cell	yes	yes	yes
89071A Tubing/Fitting Kit[1]	yes	yes	yes
89052A Peristaltic Pump[1,2]	yes	yes	yes
89053A Sipper/Sampler[1] Interface	no	yes	yes
89050A Advanced Techniques[1] Module	no	yes	yes
89072A Autosampler	no	no	yes

Footnotes

1. Included in HP 89051A Automated Sipper/Sampler System.

2. Other peristaltic pump may be substituted for use with Manual Sipper System.

Flow Cells

The system flow cell is an essential part of all sipper/sampler systems. Three sizes of flow cells are available from HP (see Table 7-4). The 8-ul cell is recommended for LC effluent applications. The larger volume cells are recommended for sipper and autosampler applications.

Each of these cells is equipped with screw fittings (M6 x 1) which allow connections with a minimum dead volume. Tubing inner diameter is 1.0 mm.

NOTE

Flow cells having an aperture of less than 2 mm require the use of the Adjustable Cell Holder (HP 89070A). Refer to page 7-24 for information on cell alignment using the Adjustable Cell Holder.

TABLE 7-4. FLOW CELLS

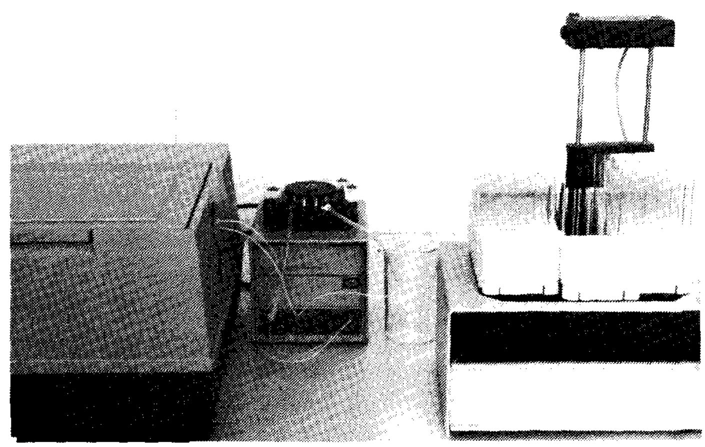
HP Part Number	Volume	Aperture	Path Length
89060A	8 μl	1 mm	1 cm
89061A	30 μl	2 mm	1 cm
89062A	80 μl	3 mm	1 cm

Flow Cell and Tubing Connections

Each of the sipper/sampler systems will require tubing and flow cell connectors. The Tubing/Fittings Kit (HP 89071A) contents are shown in Table 7-5. This kit contains all necessary connectors for the systems described below. Note however that pump tubing is supplied with the peristaltic pump (HP 89052A and Table 7-6).

A diagram showing the proper tubing connections for either sipper or sampler applications is shown in Figure 7-5. The outlet side is the same for either type of system.

To install these fittings, first remove one of the standard sample compartment plugs located on the right side of the instrument by gently pushing it from the inside. Replace the standard plug with a sipper plug (HP Part No. 89017-20101) and make all other connections as in Figure 7-5. Use one of the holes in the sipper plug for the inlet and the other for the outlet line. (The other sample compartment plug may be used for inlet and outlet of water for a thermostatted cell holder if desired.)



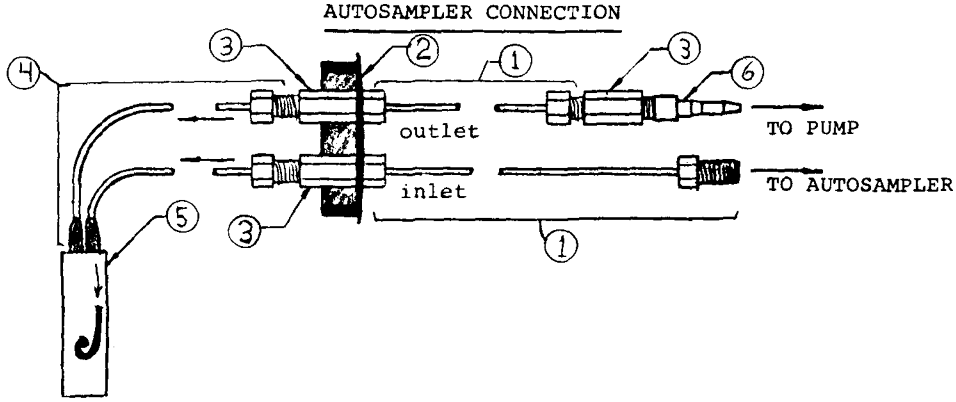
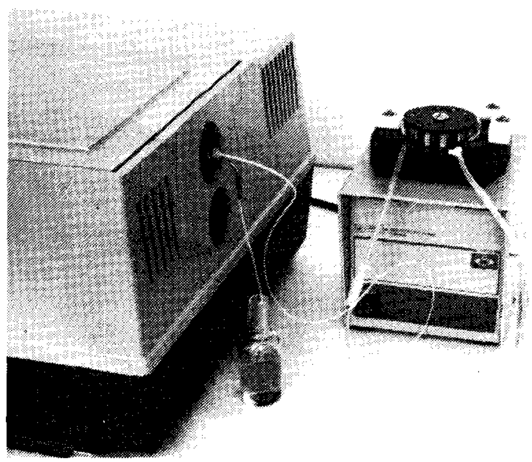


Figure 7-5. Tubing Connections for Sipper/Sampler Systems
(Diagram Continued on Next Page)



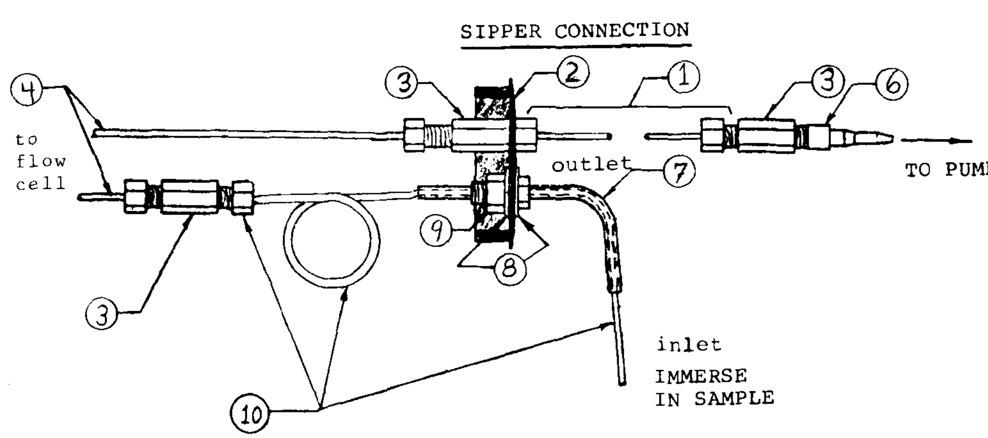


Figure 7-5. Tubing Connections for Sipper/Sampler Systems (cont.)

TABLE 7-5. TUBING/FITTINGS KIT, HP 89071A

Designation On Figure	Description	Qty.	HP Part Number
1	Tubing assembly (60 cm), teflon tubing, 1.6 mm O.D., threads 1/4 x 28	3	1530-0400
2	Sipper plug, black plastic	2	89071-20101
3	Coupler, threads 1/4 x 28	6	0100-1194
4	Flow cell tubing assembly	*	89061A or 89062A
5	Flow cell	*	
6	Adaptor	2	0100-1197
7	Sipper fitting, nickel plated, threads M6 x 1.0	1	89071-20100
8	Washer	2	3050-0103
9	Nut, threads M6 x 1.0	1	0535-0021
10	Tubing assembly (30 cm), teflon tubing, 1.6 mm O.D., threads 1/4 x 28	1	1530-2176
* Not included with HP 89071A			

Assembly Instructions (see also Figure 7-5 and Table 7-5)

1. For the outlet system, insert one end of tubing assembly (1) through the black plastic, sipper plug (2). Thread couplers (3) on each end of the tubing assembly.

2. For an autosampler system, repeat the procedure in Step 1 for the inlet system (only one coupler is shown in Figure 7-5).

   For the sipper system, assemble the sipper fitting (7), two washers (8) and the nut (9) on the sipper plug as shown in the figure. Insert the teflon tubing (10) through the sipper fitting and thread on a coupler (3).

3. Connect the flow cell (5) and its associated tubing assemblies (4).

4. Thread on an adaptor (6) for connection to the peristaltic pump tubing.

Peristaltic Pump

The HP 89052A Pump is recommended for use in sipper/sampler systems. It is a fixed speed (72 RPM) pump which can be operated either manually or under control by the HP 8451 through the sipper/sampler interface (HP 89053A), and using enhanced BASIC commands accessible with the alphanumeric keyboard. Figure 7-6 shows the manual pump controls.

Six pieces of tubing are supplied with the pump as listed in Table 7-6. ml/min.

TABLE 7-6. PUMP TUBING

Qty	I.D.	Approximate Flow Rate
2	2.8 mm	34.6 ml/min
2	1.52 mm	14.4 ml/min
2	0.76 mm	3.8 ml/min

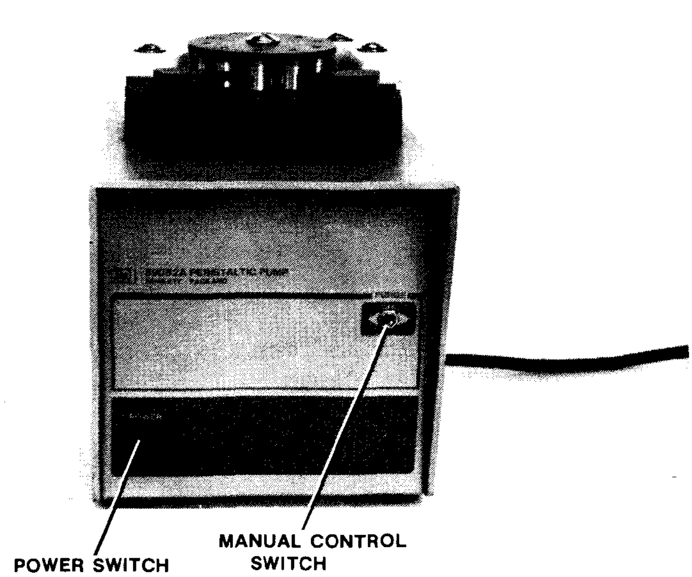


Figure 7-6. Peristaltic Pump (HP 89052A)

To install the pump tubing, release the collar over the rotor by pressing on the lever as shown in Figure 7-7. Wrap the tubing around the rotor, fastening the tubing stops in position (see Figure 7-7). Close the collar over the tubing. Adjust the tension on the tubing using the thumb screw.

If necessary for cleaning, the rotor may be easily removed by removing the large screw in its center. An outlet drain is provided in the event that liquid becomes spilled on the rotor area.

For manual operation, simply turn the power switch ON and flip the manual pump control switch (see Figure 7-6) to rotate the pump in the desired direction.

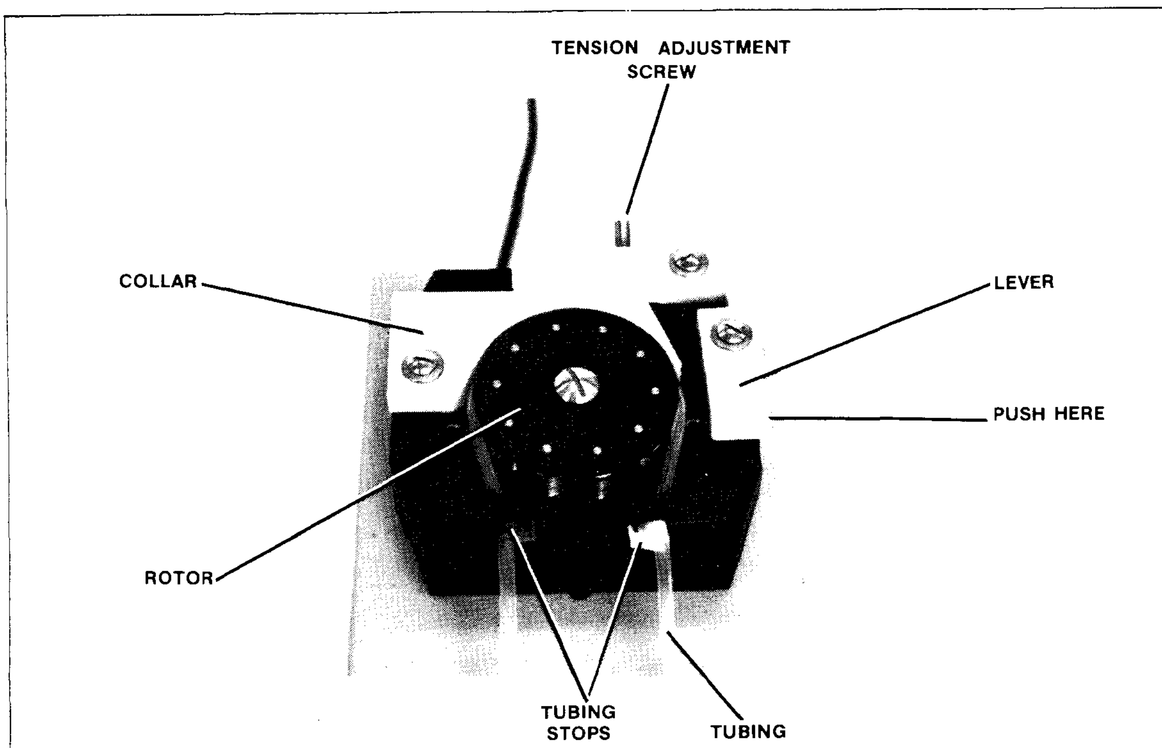


Figure 7-7. Connection of Pump Tubing

Remote Pump Control

The HP 89052A Pump can be operated through the Sipper/Sampler Interface Module (HP 89053A) for automatic pumping of samples into the flow cell. This system requires installation of the HP 89053A Module as described for other plug-in modules (see page 3-6). The interface has two output cables, one for the peristaltic pump and one for the HP 89072A Autosampler (see Figure 7-8). Simply connect the pump cable to the socket on the rear panel of the pump.

The pump commands can be entered directly from the alphanumeric keyboard or can be part of a BASIC program.

The command to turn the pump on is

PUMP ON EXECUTE (for clockwise rotation)

PUMP ON -1 EXECUTE (for counterclockwise rotation)

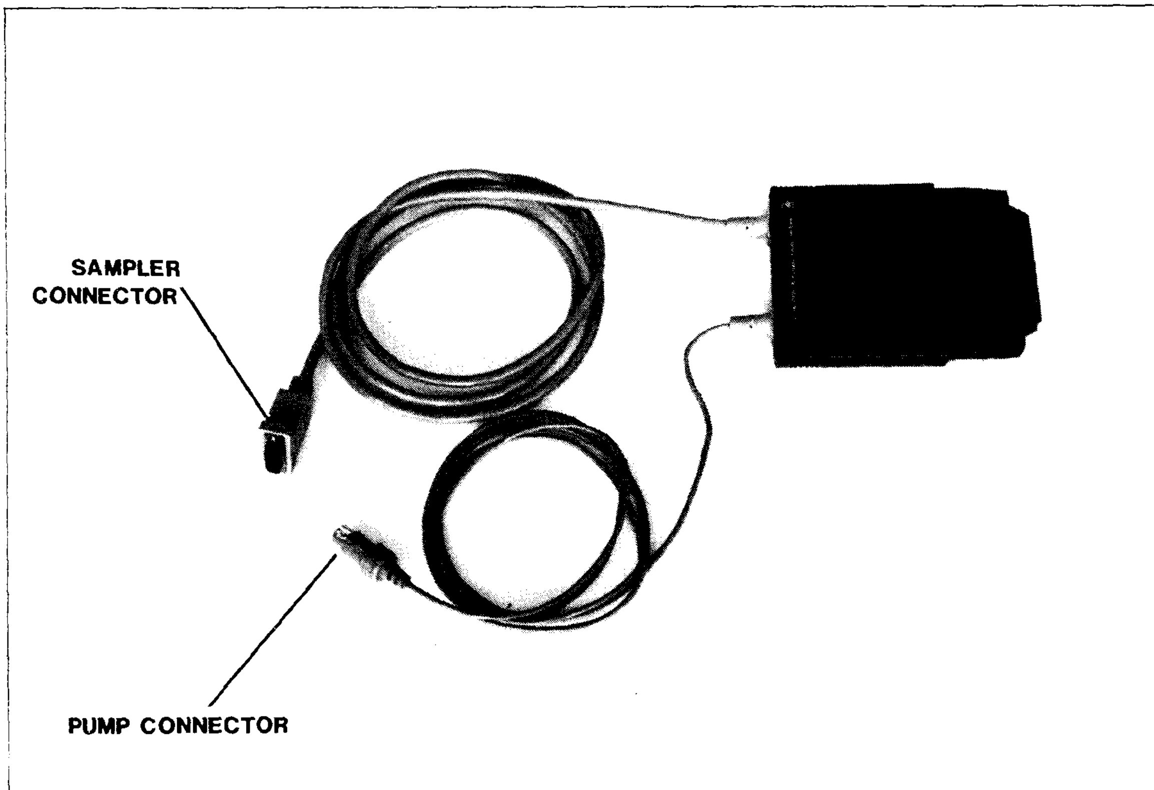


Figure 7-8. Sipper/Sampler Interface Module

The command to turn the pump off is

PUMP OFF EXECUTE

For examples of how these commands are used in a program refer to Section 8, BASIC Programming.

Interfacing the HP 89072 Autosampler

The HP 89072 Autosampler shown in Figure 7-9 provides automatic transfer for up to 114 samples. A wash station is also included. The unit is directly interfaceable to the HP 8451. Simply connect the autosampler cable from the Sipper/Sampler Interface Module (Figure 7-8) to the socket on the rear of the

HP 89072 Autosampler. Feed the inlet tubing (Figure 7-5) through the probe until it extends just beyond the probe tip. Fasten the tubing in place with the tension screw near the top of the probe.

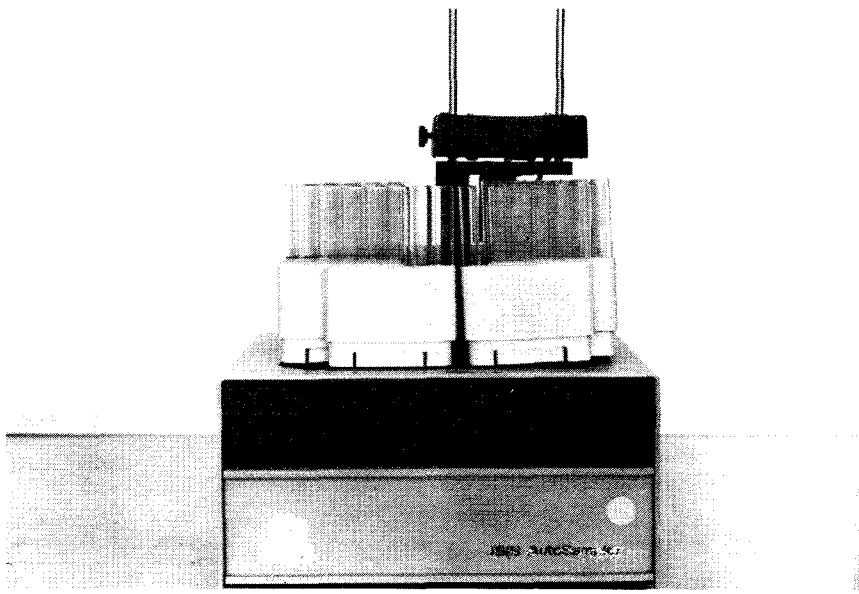


Figure 7-9. HP 89072A Autosampler

NOTE

Refer to the HP 89072 Autosampler Operator's Manual for complete information on specifications and manual operation.

There are five commands which can be used to control the autosampler in remote mode. The commands may be entered directly through the alphanumeric keyboard or may be part of a BASIC program.

The commands are as follows:

PROBE UP

PROBE DOWN

SAMPLE POSITION (moves the probe to a position above the sample tube)

WASH POSITION (moves the probe to a position above the wash station)

TRAY ADVANCE (advances the sample tray one position)

TRAY START (advances the sample tray to tube number 1)

The commands are internally implemented such that the sampler raises the probe (if down) prior to moving laterally to the sampler or wash position or before advancing the tray. This prevents accidental damage to the sampler if the operator accidentally omits the PROBE UP command.

Refer to Section 8, BASIC Programming for an example of how to use these commands in a program.

INSTRUCTIONS FOR USING ADJUSTABLE CELL HOLDER

Install the adjustable cell holder in the sample compartment of the HP 8451 and screw in the hold-down screws part way (the hold-down spring should be compressed, but the screws should not be snug). See Figure 7-10.

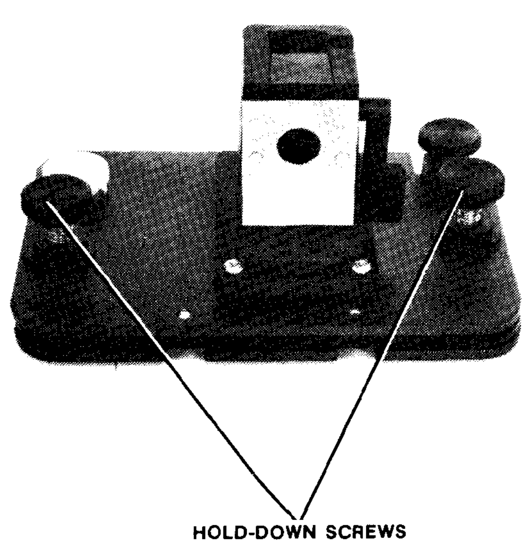


Figure 7-10. Installing Adjustable Cell Holder

Insert a solvent filled cuvette (or flow cell) into the adjustable cell holder.

Flip the lever to the vertical position in order to clamp the cuvette in position.

Adjust the cuvette position in the following order: translation, rotation, height. The adjustment procedure is as follows:

Intensity Monitor

To monitor the intensity on the CRT, enter the following keystrokes:

INTENSITY 1,1 EXECUTE
λ 360 EXECUTE
ABSORBANCE 360 EXECUTE
Y SCALE 0 TO 17000 EXECUTE
MEASURE .1, .2, 0, 120 EXECUTE (a 120-second measurement)

After the level of the output has been determined, the Y-scale of the CRT can be readjusted to give greater resolution (e.g., Y-SCALE 6000 to 8000 EXECUTE). If the measurement terminates before all adjustments are finished, it can be restarted by pressing

MEASURE EXECUTE

These keystrokes will produce an output of intensity versus time on the CRT. The cuvette position should be adjusted in each direction for maximum intensity.

Approximately center the rotation adjustment.

Translation Adjustment

Move the cell holder back and forth while monitoring the intensity output on the CRT. When an intensity maximum is found, tighten the translation lock screw (see Figure 7-11).

Rotation Adjustment

Adjust the rotation in a similar manner. When the intensity maximum is found, tighten the rotation lock screw (see Figure 7-11).

Tighten the hold-down screws to firmly clamp the cell holder down on its base.

Height Adjustment

Perform the vertical adjustment using the thumbscrew at the rear of the cell holder. The thumbscrew will only push the cuvette upwards. To move the cuvette downwards it will be necessary to move the lever to the horizontal position to loosen the cuvette, and allow the cuvette to fall down onto the thumbscrew (see Figure 7-11). Then lock the cuvette in position.

Since these adjustments may not be entirely independent, the location of the optimum cuvette position may require readjustments in each direction.

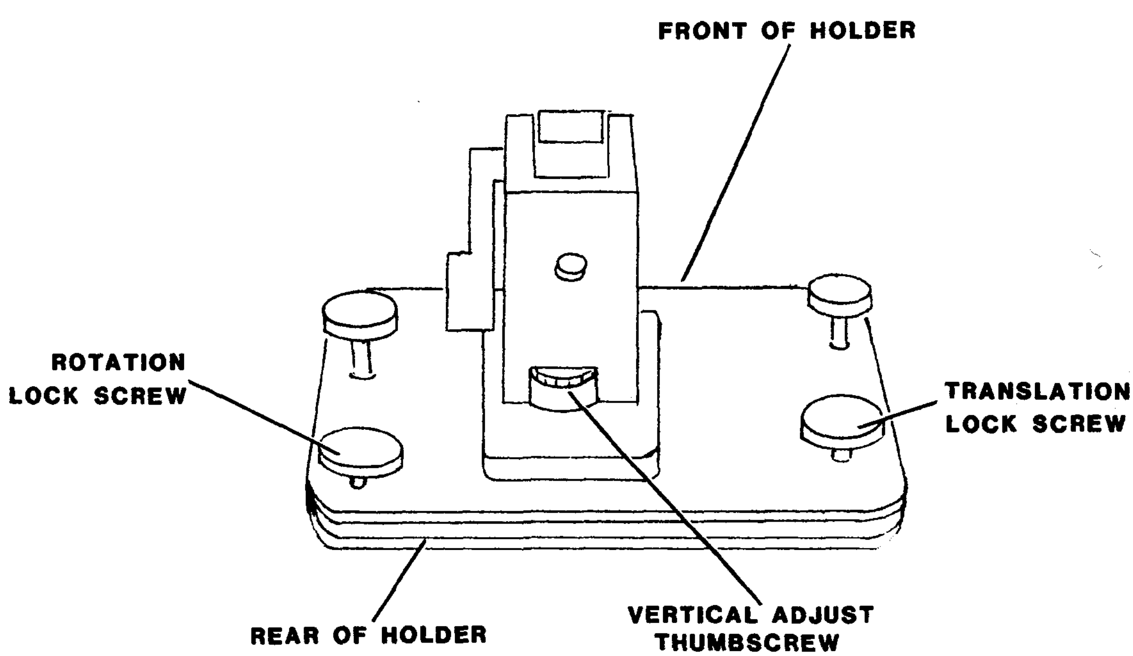


Figure 7-11. Adjustment Screws

Do this in the following order:

a. Loosen hold-down screws
b. Loosen translation lock screw
c. Recheck translation adjustment
d. Tighten translation lock screw
e. Loosen rotation lock screw
f. Recheck rotation adjustment
g. Tighten rotation lock screw
h. Tighten hold-down screws
i. Recheck vertical adjustment

INSTRUCTIONS FOR USING THERMOSTATTABLE CELL HOLDER

A thermostatted water bath is required in order to use the thermostattable cell holder. If required, the stirrer module (HP Part No. 89055A) may be ordered separately.

Setup

1. Install the thermostattable cell holder in the sample compartment of the HP 8451.

2. Connect the water inlet and outlet tubing to the manifold and stirrer (see Figure 7-12). If a faster stirring speed is desired than can be obtained by connecting the manifold and stirrer in series, a separate pressurized water or air source can be used to drive the stirrer.

   Silicon tubing, 3/16" I.D., is recommended for connecting the manifold and stirrer.

   Tubing connected to the lever side of the cell holder can be routed under the tubing restraint tab to keep from interferring with the light beam.

   Make sure all tubing is securely attached. The tubing may expand when heated and if it is not secure, a leak may result.

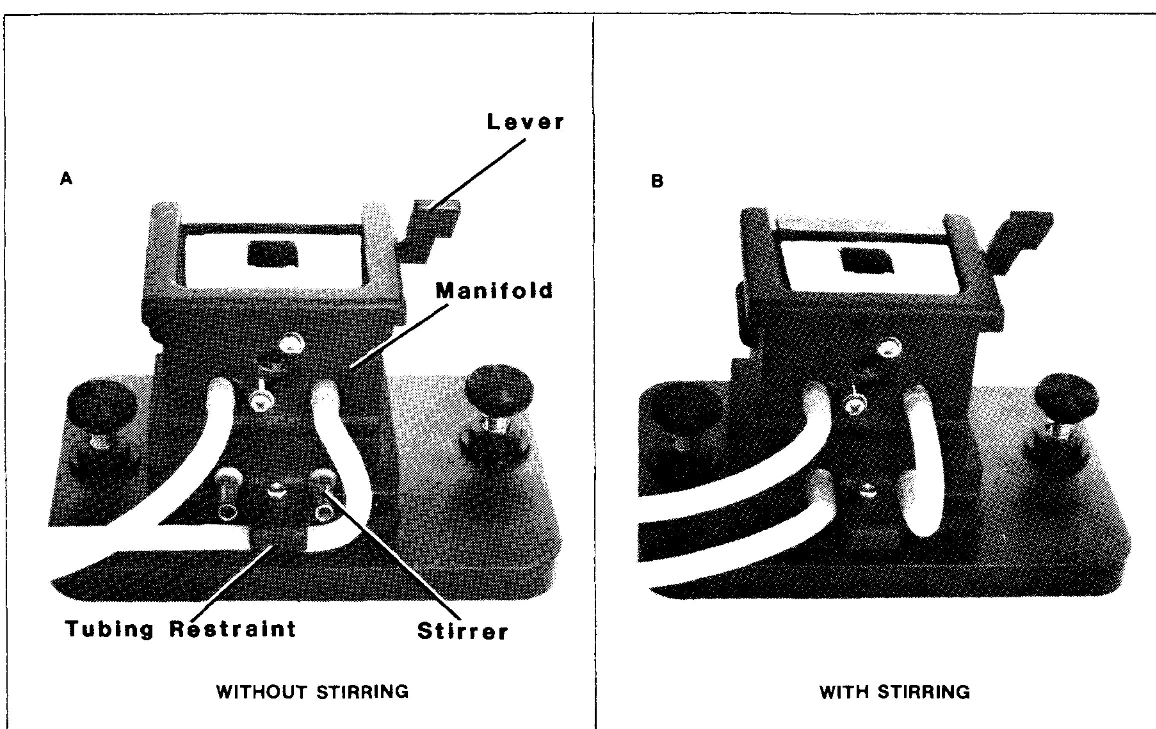


Figure 7-12. Connecting Water Tubing to the Manifold and Stirrer

3. Insert the cuvette. If the sample requires stirring, a stirring flea (HP Part No. 9301-0607) must be placed in the cuvette. Flip the lever to the vertical position to clamp the cuvette securely in position.

4. Begin pumping thermostatted water through the cell holder.

   If required, activate the stirrer drive system. A pinch clamp can be used to control the sample stirring speed.

   Wait for the cuvette and sample to reach thermal equilibrium before making any measurements.

   When not in use, it is best to disconnect and drain both the thermostattable cell holder and stirrer.

NOTE

> When absorbance measurements are being made, the lever must be in the vertical position for optimum optical performance.

FILTER WHEEL

To achieve optimum measurement conditions, UV cut-off filters may be required for spectral measurements of photosensitive samples. Such filters modify incident radiation at the sample. The deuterium lamp used in the HP 8451 provides radiation that exceeds the range of 190 nm to 820nm so that spectral measurements can be made in the wavelength region that is bounded by 190nm and 820nm. If a sample is photosensitive in this wavelength range, the sample is more likely to be degraded by the higher energy UV radiation. In some cases, the UV radiation is responsible for changes observed in the visible spectra of a sample (in nature this occurs when one sunburns or tans). When the four position filter wheel shown in Figure 7-13 is placed between the lamp and the sample, the incident UV radiation at the sample can be selectively modified. The typical transmission characteristic for each of the four positions of the filter wheel (HP part number 08451-60302) is shown in Figure 7-14. These are designated as follows:

POSITION	TRANSMISION CHARACTERISTIC
0	no filter, 100% T at all wavelengths
1	UV roll-off
2	265 nm UV cut-off (at 50% T)
3	295 nm UV cut-off (at 50% T)

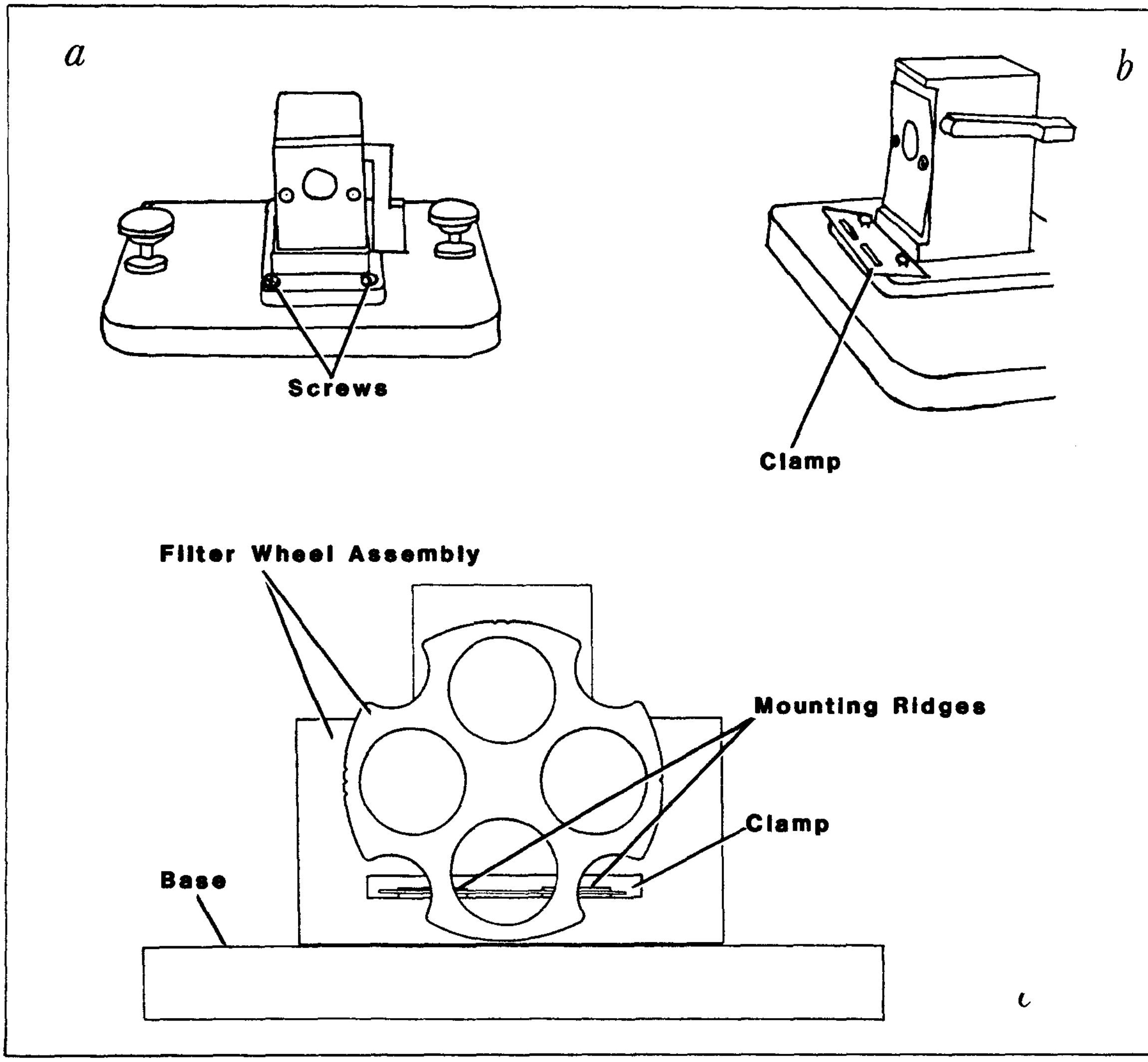


Figure 7-13. Mounting the Filter Wheel

Figure 7-15 diagrams the effect of using a 295 nm filter in the HP 8451. The filter wheel may be mounted on any of the HP 8451 sample holders (08451-60104 standard, 89070A Adjustable, 89054A Thermostattable).

Assembly

1. Remove the sample holder from the sample compartment.

2. Remove the two screws shown in Figure 7-13a.

3. Position the filter wheel clamp as shown in Figure 7-13b then replace but do not fully tighten the two screws. Note the upward tilt of the filter wheel clamp. It may be helpful to invert the sample holder before proceeding to the next step.

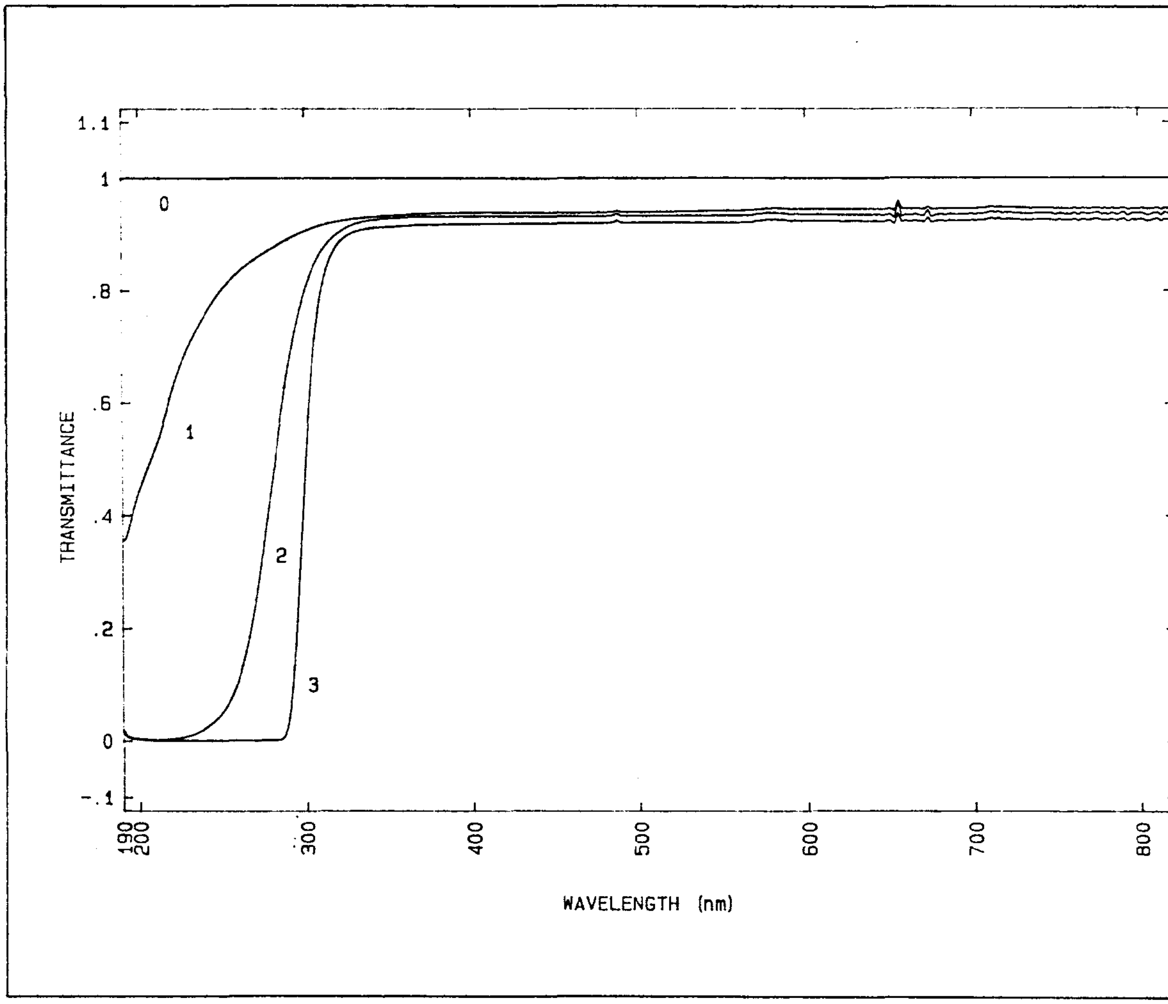


Figure 7-14. Transmission Characteristics

4. Position the filter wheel assembly so that the filter wheel clamp engages the mounting ridges in the filter wheel assembly. The base of the filter wheel assembly must be flush with the sample holder base (see Figure 7-13c) and parallel with the front edge of the sample holder base (i.e., the filters must be perpendicular to the light beam when installed in the spectrophotometer).

5. Tighten the two screws shown in Figure 7-13a to secure the filter wheel assembly to the sample holder.

Disassembly and Storage Instructions

1. Loosen but do not remove the two screws shown in Figure 7-13a.

2. Invert the entire sample holder and separate the filter wheel assembly from the sample holder.

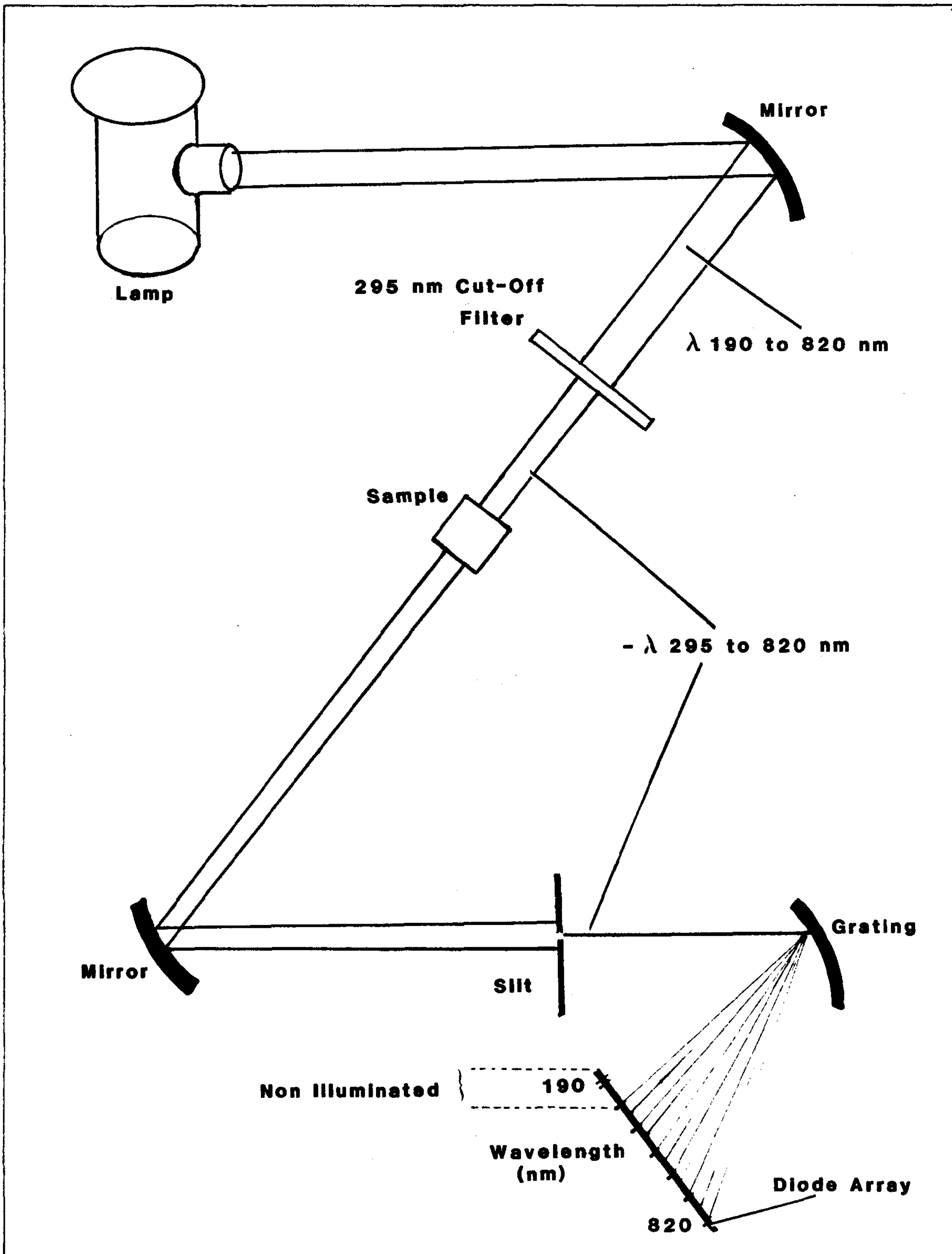


Figure 7-15. Effects of 295 nm Cut-Off Filter

3. The filter wheel clamp may be left in place or removed. In either case, retighten the two screws shown in Figure 7-13a.

4. Store the filter wheel in a clean plastic bag.

The spectra shown in Figure 7-14 were generated by the following procedure:

1. Install a mounted filter wheel in the sample compartment and move the filter wheel to position 0.

2. Turn on the HP 8451 and press TRANSMITTANCE EXECUTE.

3. Press REFERENCE EXECUTE.

4. Move the filter wheel to the position to be measured.

5. Press MEASURE EXECUTE.

The choice of when to use a cut off filter and which filter to use should be made by the analyst after considering all the parameters for measurement optimization (see Section 4, Operation). If it is determined that a filter is needed (e.g., to eliminate data invalidation), the filter should transmit the wavelengths required for analytical information and block the wavelengths that contribute to sample degradation (or data invalidation). For example, a 300 nm cut-off filter will effectively eliminate radiation of less than 300 nm from reaching the sample while measurements are made in the 350 nm to 450 nm range.

Regardless of the display limits, the 295 nm cut-off filter blocks most radiation below 295 nm in the reverse optics design of the HP 8451. With this filter in the sample path, no useful analytical data can be obtained in the range from 190 nm to nearly 295 nm.

If a UV cut-off filter is not needed for occasional sample measurments, the filter wheel must be moved to position 0. When the filter wheel is not needed for extended periods of time, it should be removed from the sample holder and stored in a clean plastic bag.

Like the exterior optical surfaces of the spectrophotometer, the filters of the filter wheel must be kept clean in order to pass wideband radiation. These filters may be cleaned with isopropanol and lens tissue (see procedure for cleaning exterior optical surfaces in Section 9, Maintenance). Dirty filters (e.g., those smudged with fingerprints) will degrade spectrophotometric performance.

Section 8

BASIC PROGRAMMING

INTRODUCTION

Purpose of BASIC

The photometric measurement of a sample is often only the first step toward obtaining a final answer. This information must be interpreted, combined with other data and otherwise "massaged" until the required result is obtained.

As one example, the concentration of an active ingredient in a drug formulation can be determined using a UV/VIS spectrophotometer. The drug manufacturer however, is also required to report the uniformity of the active ingredient from tablet to tablet or other dosage form. The calculations are quite straight-forward, but require either considerable operator time or access to a computer system.

The HP 8451 BASIC Language programming provides this computing capability in the analyzing instrument itself. With an appropriate program, the 8451 can measure, determine the concentration of the individual samples, calculate the statistical information required, flag questionable results, format, and print a report of the final results without any need for manual handling of the data.

BASIC has access to analytical information generated by the 8451. Information can also be entered through either the built-in functional keyboard or the external alphanumeric keyboard. Therefore, BASIC can operate upon both system-generated and user-generated information. This makes it suitable for on-line calculations (process control), consolidation of analytical data, control of other instruments, and the casual calculating jobs that frequently arise in the laboratory.

What is BASIC

BASIC stands for Beginner's All-purpose Symbolic Instruction Code. It was designed at Dartmouth College as part of their "every student should know about computers" philosophy. It has changed considerably from its original form (it is no longer accurate to call it a beginner's language) and has gained wide acceptance because of the ease of learning and using it.

One unfortunate consequence of BASIC's popularity is that now there are many BASICs. Computer manufacturers have designed different versions, each incorporating some new "nice features" to make the language more powerful and (hopefully!) easier to use. To reduce the resulting confusion (But which BASIC are you talking about?) the American National Standards Institute has written a standard defining "minimal" BASIC, a set of commands and statements which will be common to all versions of BASIC. Individual manufacturers may add additonal features if desired.

What is HP 8451 BASIC

The HP 8451 BASIC is based upon the HP 85 personal computer. The microprocessor and other integrated circuits of the HP 85, including the software, have been incorporated into the 8451. Not only does this provide BASIC language capability, it also allows the 8451 to utilize the standard interfaces (HP-IB, RS-232, GP-IO, DSN/DL) and is compatible with the peripherals (plotter, printers, discs, relay actuator, etc.) and many of the software packages of the HP 85 computer. This BASIC exceeds the latest American National Standard for Minimal BASIC and in many areas it includes enhancements to this standard.

In addition to the standard HP 85 BASIC and enhancement ROMs, the HP 8451 has additional features. First, all of the commands that can be executed from the built-in functional keyboard are actually extensions of the BASIC instruction set and are legal program statements. Second, there are additional commands and functions that became available with the alphanumeric keyboard accessory. All of the commands, statements and functions allow BASIC to interact with the instrument. In fact, the 8451 can be executing a BASIC program while a measurement sequence is in progress. This provides the capability to set up, control, evaluate and interact with the spectrophotometer in real-time.

KEYBOARD KIT FOR ACCESS TO BASIC COMMANDS

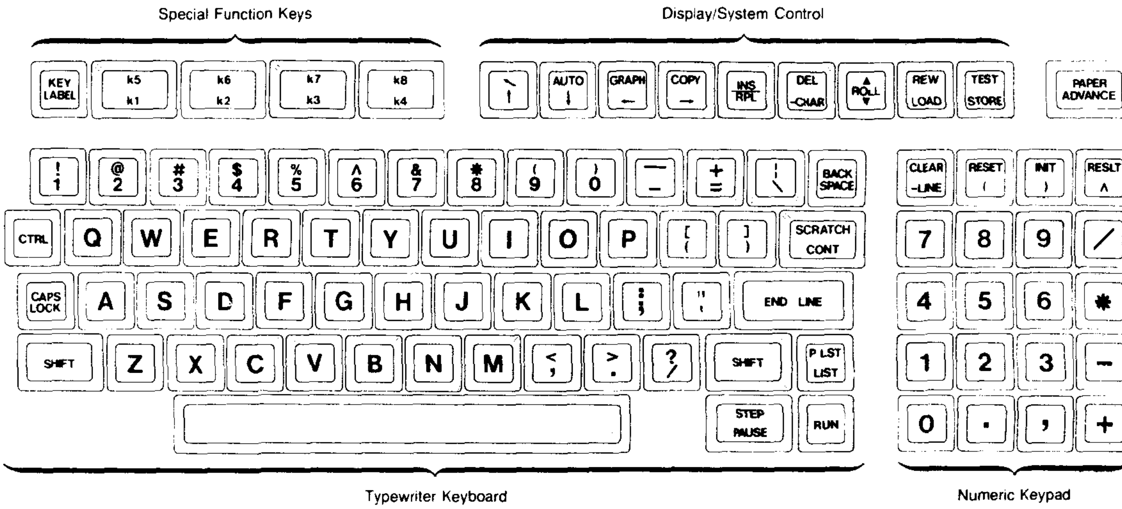
The capability to write BASIC programs on the HP 8451 is provided by the HP 89057A Alphanumeric Keyboard Kit. This kit consists of a 98155 Keyboard, an 89057-60100 Keyboard Interface Module and an 00085-90002 HP 85A Owner's Manual and Programming Guide. The keyboard kit allows access, along with the HP 89050A Advanced Techniques Module, to the HP 85 BASIC commands and some additional spectrophotometric commands not available with the built-in functional keyboard. It also allows the ability to utilize the applications packages available for the HP 85.

It is recommended that a disc drive (see requirements for disc operation, Section 7) is also added when writing BASIC programs. Once written, programs can be permanently stored on a disc. These programs can be recalled and run with either the alphanumeric or functional keyboards. Thus a procedure may be written in a research laboratory and passed on to a quality control laboratory (which may not have an alphanumeric keyboard) for routine analysis.

Keyboard Configuration

Basically, the HP 85 Computer and the HP 8451 Spectrophotometer are compatible systems. At a first glance, the HP 85 keyboard and the alphanumeric keyboard seem very different (see Figure 8-1). For all practical purposes, the HP 98155 keyboard is a subset of the HP 85 keyboard and, as such, operates in a similar manner. While specific keys (such as load, store, init, list, PLST) are not found on the 98155 keyboard, they can be performed by typing the

HP 85A Keyboard



Alphanumeric Keyboard

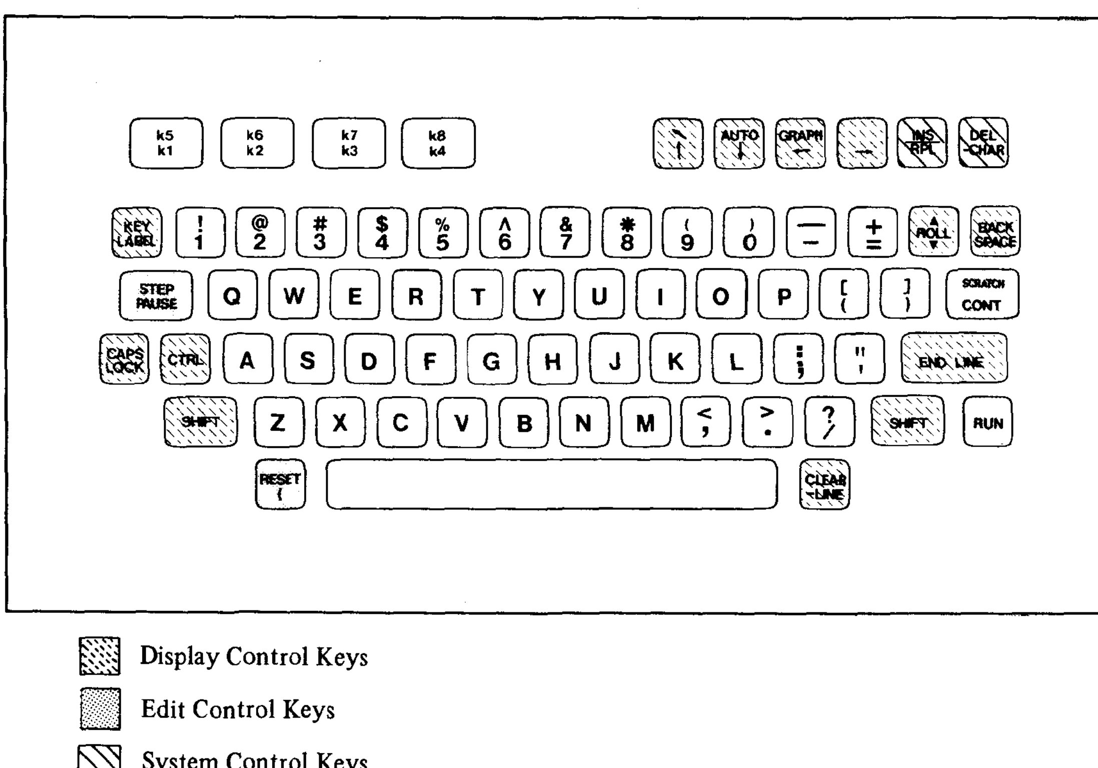


Figure 8-1. Keyboards for HP 85 and HP 8451 Spectrophotometer

words followed by EXECUTE or ENDLINE. Keys such as copy, paper advance, numeric pad, and arithmetic operators are located on the HP 8451 functional keyboard. The TEST key also is not on the 98155 keyboard, but the same test can be performed by using the diagnostic mode of the 8451 (refer to Diagnostic Section). Refer to Tables 8-1 to 8-3 for operation of the display control, editing, and system control keys.

PROGRAMMING THE HP 8451

If you do not know BASIC:

It is a good idea to get the BASIC training (HP 85) applications pac, or to take an HP 85 BASIC training course offered by your local sales office. Programming is both a science and an art, and either of the above choices will provide a good grasp of efficient programming techniques.

If you already know BASIC:

It is best to start with the HP 85 Owner's Manual and Programming Guide. The first four sections of the manual will help describe operations that apply to the HP 85 and 8451. Remember to use the 98155 keyboard instead of the HP 85 keyboard (the tape cartridge operations can be done with a disc as well). Then use the operating manual as a source for any questions as to command syntax and system operations.

The following pages will describe how to use the spectrophotometer commands in a BASIC program, starting with simple operation to setup procedures, then a description of the extended spectrophotometer commands and how they can be used to enhance the capability of the 8451, and finally some examples of BASIC programs for the 8451.

Spectrophotometer Commands in BASIC

As mentioned before, all of the spectrophotometer commands described in Section 5 are extensions of the BASIC language of the HP 85 operating system and, as such, they can be used as legal statements in a BASIC program. In addition, the data from measurements and/or calculations from the spectrophotometer portion of the instrument is easily accessible by BASIC with simple functions. A function performs an operation with a given value, or set of values, that yield a single output. These values are called "arguments" or sometimes "parameters". An argument is often just a single number, but it may be a mathematical expression containing variables or other functions. Most functions require one argument, but there are some that require none. These functions, along with some additional commands (see Table 8-4), are available only with the alphanumeric keyboard accessory. The combination of these commands and functions with the standard HP 85 BASIC allows flexible instrument setup, data acquisition, data evaluation, decision making, and report generation.

TABLE 8-1. DISPLAY CONTROL KEYS

Key Symbol	SHIFT N	SHIFT Y	Name	Function
↖ ↑	X		Cursor Up	Moves the cursor upward on the CRT screen.
↖ ↑		X	Home	Moves the cursor to the top, left corner of the CRT screen.
AUTO ↓	X		Cursor Down	Moves the cursor downward on the CRT screen.
AUTO ↓		X	AUTO	Typing aid — starts automatic line numbering. Beginning line number and numbering interval are optional. Default is 10. Execute by pressing **END LINE**.
GRAPH ←	X		Cursor Left	Moves the cursor to the left of its current position.
GRAPH ←		X	GRAPH	Sets system display to graphics mode showing current graphics display. Press any alphanumeric key to return to normal alphanumeric display.
→	X		Cursor Right	Moves the cursor to the right of its current position.
		X	Blank key	Copies information displayed on the CRT to the built-in printer.
KEY LABEL	X		KEY LABEL	Recalls the current labels for the special function keys and displays them on the CRT. It also moves the cursor to the upper left corner of the display.
▲ ROLL ▼	X		Roll Down	Rolls the display down toward the bottom of the CRT screen.
▲ ROLL ▼		X	Roll up	Rolls the display up toward the top of the CRT screen.
BACK SPACE	X		BACK SPACE	Erases characters while positioning the cursor backwards in one space increments.
BACK SPACE		X	Rapid Backspace	Backspaces to the beginning of the line. Holding the key automatically repeats without stopping at the beginning of the line. Each preceding line is erased in succession until the key is released.

TABLE 8-1. DISPLAY CONTROL KEYS (Continued)

Key Symbol	SHIFT		Name	Function
	N	Y		
CAPS LOCK	X		CAPS LOCK	Locks the alphabetic characters of the keyboard into lower case.
CTRL	X		CTRL	Used in conjunction with other keys to provide ASCII control codes.
END LINE	X		END LINE	Provides the end-of-line code to the computer. 1) Edit Mode — automatically generates a carriage return and a line feed to move the cursor down to the next line. 2) Terminates an input. 3) Stores program lines during program development. 4) Tells the computer to perform live keyboard calculations and operation.
SHIFT		X	SHIFT	Provides SHIFTed case function of all alphanumeric keys, special function keys and display control keys on the keyboard. When in computer mode, it provides lower-case alphabetic characters. When in typewriter (edit) mode, it provides upper-case alphabetic characters. This key must be pressed at same time as selected key. Function stops when key is released.
CLEAR -LINE		X	CLEAR	Clears 16 lines from the display starting at the cursor position. Data above the cursor is rolled off screen. When completed, it homes the cursor.
CLEAR -LINE	X		-LINE	Deletes a line from the cursor to the end of the line.

NOTE

When the CAPS LOCK key is depressed, numerous keys on the HP 8451 keyboard will not function. For full operation of the CAPS LOCK key must not be depressed.

TABLE 8-2. EDITING KEYS

Key Symbol	SHIFT N	SHIFT Y	Name	Function
INS/RPL	X		RPL	Replace mode— Normal mode of operation. Replaces old text with new text at cursor location. Toggles to INS mode.
INS/RPL		X	INS	Insert Mode — provides a second cursor to left of original cursor. Allows inserting characters between cursors. Toggles to RPL mode.
DEL/-CHAR	X		- CHAR	Deletes character above cursor. Each stroke deletes a character. Holding key down rapidly deletes characters.
DEL/-CHAR		X	DEL	Typing aid — deletes specified line or section of a program. Pressing key puts DELETE on command line. Requires operator to type line number or beginning and ending line numbers. (Must be by line number or first and last line number of a section to be deleted.) Execute by pressing **END LINE**.

Edit Control Keys. The edit control keys provide the operator a means to control the information which has been entered into the memory. Table 8-2 lists all the editing keys and provides a brief description of their function.

TABLE 8-3. SYSTEM CONTROL KEYS

Key Symbol	SHIFT N	SHIFT Y	Name	Function
STEP PAUSE	X		STEP[1]	Allows the operator to execute a program one line at a time. Immediate execute key.
STEP PAUSE		X	PAUSE[1]	Allows the operator to halt a program in process.
SCRATCH	X		SCRATCH[1]	The SCRATCH command clears the computer memory. The command is executed by pressing **END LINE**.
CONT	X		CONTINUE[1]	Immediate execute key — CONTINUEs execution of a program that has been halted by a PAUSE command.
RUN	X		RUN[1]	Immediate execute key — it first initializes the current program, then executes the program.
RESET (		X	RESET[1]	Resets the computer and all interfaces. Any program loaded remains loaded, but will be reinitialized upon execution.
RESET (	X		LEFT PAREN	Left parenthesis.

System Control Keys. The control keys listed in Table 8-3 provide display control as well as normal typewriter functions.

Simple Programs

Let us start by programming a very simple sequence of operations. First, reset the instrument back to its startup condition, set the wavelength range from 300 to 600 nanometers, set data processing to absorbance, specify the CRT as the output device for plotting, Y-scale 0 to 2, and start a measurement.

You will notice that in the program below, the commands appear exactly as they would from the functional keyboard except that they are preceded by a line number. As they are entered, the commands are checked for proper syntax, stored if correct, but not actually executed until the program is run. This also means that any out-of-range parameters are not detected until the commands are executed. This program, when run, will execute the statements in order from the lowest line number.

```
10  ERASE STATUS
20  LAMBDA 300 TO 600
30  ABSORBANCE
40  PLOTTER 1
50  Y-SCALE 0 TO 2
60  MEASURE
70  END
```

Use of Variables in Programs

There are some occasions where it may be necessary to allow the parameters of the instrument to change during the running of a program. This could be anything from changing the wavelength range to entering the concentration of a standard. In these cases, one can use variables instead of final values for the parameters.

Example

Let us write a program to ask the user to enter the start λ and then the end λ and then set the wavelength range.

```
10  DISP "ENTER START λ";
20  INPUT S
30  DISP "ENTER END λ";
40  INPUT E
50  LAMBDA S TO E
```

When this program is executed, at line 50 the start of the wavelength range will be set to the current value of S and the end of the wavelength range will be set to the current value of E.

In later examples, we will again see the use of variables as parameters in BASIC programs.

USING THE MEASURE COMMAND IN A BASIC PROGRAM

In the HP 8451, a number of spectrophotometer-related commands have been added to BASIC. Most require the "Advanced Techniques Module" (see Table 8-4), but STOP MEASURE, NMEASURE, STDEV (n) and VALVE (n) do not and come with the standard HP 8451A.

TABLE 8-4. EXTENDED BASIC COMMANDS AND FUNCTIONS

Commands	Page No.
CALCULATE - Data processing only, no output.	8-16
ERASE MEMORY n - Erases entire extra memory or loc n.	8-28
OFF MEASURE - Deactivates ON MEASURE command.	8-23
ON MEASURE - Branches after each measurement.	8-23
PROBE UP - Moves sampler probe up if down.	8-20
PROBE DOWN - Moves sampler probe down if up.	8-20
PUMP OFF - Turns pump off.	8-20
PUMP ON [n] - Pump on CCW if n<0, else CW.	8-20
RECALL MEMORY n - Recalls extra memory loc n.	8-26
SAMPLE POSITION - Moves probe up and over tube.	8-20
+ STOP MEASURE - Stops measurement in progress.	8-23
TO MEMORY n - Stores in loc n, extra memory.	8-26
TRAY ADVANCE - Sampler tray forward one pos.	8-20
TRAY START - Tray to next starting position.	8-20
WASH POSITION - Probe up and over wash tube.	8-20
Functions	
* (For functions below; 9.9E499 = invalid data)	
INDEPSTD - Indep of stds from multicomp calc.	8-17
MULTICONC (n) - Conc of Std n from multicomp.	8-17
MULTIDEV (n) - Std dev of conc for std n.	8-17
+ NMEAS - Set number of completed measurements.	8-11
PEAK# (n) - n=0, get # peaks; n=1-20, λ or t.	8-16
RELFITERR - Fit error from multicomp calc.	8-17
STATCONC (n) - Get std n conc in STATUS CONC.	8-18
STATCONCABS (n) - Std n absorb in STATUS CONC.	8-18
STATCONCERR (n) - % error std n in conc calc.	8-18
STATCONCK (n) - Get Kn (n=0,1,2) STATUS CONC.	8-17
STATCONCKDEV (n) - Std dev of Kn in STATCONCK.	8-17
STATUS MEMORY (n) - n=0, avail mem; n=1, test.	8-29
+ STDEV (n) - Std dev display data at n=λ or t.	8-16
+ VALUE (n) - Value at n=λ,t, or -1 for result.	8-13

+ Commands and functions in standard system. All others are in the Advanced Techniques Module.

Since the purpose of a spectrophotometer is to acquire photometric data, it is important to understand how the measurements work and how to use the MEASURE command in a BASIC program. The HP 8451, with its dual microprocessor system, allows both the measurements and a BASIC program to run simultaneously. This type of arrangement has the advantage of being able to have access to and to evaluate the data in real-time during the measurement sequence.

When the MEASURE command is executed, the current measurement timing and wavelength parameters are sent to the measurement processor, and the program execution continues. Therefore, the MEASURE command only starts the measurement sequence. When an individual measurement is complete, the measurement processor transfers the data to the user or system processor. The user processor will periodically check for a data ready signal, and when detected, performs the current data processing and then sends the information to the current output specified.

NOTE

> The user or system processor only checks for a measure-complete signal at the end of a program line. For very fast measurement intervals, avoid program lines which require long execution times.

The NMEAS Function

The NMEAS function returns the number of completed measurements since the last MEASURE. After a MEASURE command is executed, NMEAS is reset to a value of zero and every time a measurement is complete, the NMEAS value is incremented by 1.

For the simple case where a single measurement is made, wait for the measure to complete like this:

```
.
.
.
40  MEASURE 1
50  IF NMEAS = 0 THEN 50
.
.
.
```

In this example, line 40 will start a one-second measurement. The BASIC program will continue immediately to line 50. The value of NMEAS will be equal to zero until the measure has completed. As long as NMEAS = 0 then the program will wait at line 50. When the measure completes, NMEAS will increment by 1. The next time line 50 is executed, NMEAS will not be equal to zero and the program will continue to the next line. If there are any

questions as to how the IF, THEN statements work, refer to the HP 85 Operator's Manual.

The NMEAS function can also be used when performing a measurement sequence. In this example, we will select a single wavelength at 500 nm and make a measurement every one second for 20 seconds. The program should wait for each measurement before proceeding. One way to write the program sequence is as follows:

```
 .
 .
 .
40  LAMBDA 500
50  MEASURE 1,1,0,20
60  X = 0
70  IF NMEAS = X  THEN 70
80    .
90    .
100 X=X+1
110 IF X<21 THEN 70
 .
 .
 .
```

The example starts at line 40 where the wavelength is set to 500 nm. The MEASURE sequence is specified in line 50 where we will take a one-second measurement, every second, starting at zero seconds and ending at twenty seconds. Therefore, if we use the equation to determine the total number of measurements (INT ((e-s)/r) +1), we calculate that there will be 21 measurements performed. Again, remember that line 50 will only start the measurement sequence, and the program will continue to line 60 where the variable X is initialized to zero. Line 70 is used to wait for the measurements to complete. The first time the program reaches line 70, NMEAS=0 and the program calls for a wait for the first measurement. Then after the first measurement, NMEAS=1 and the program proceeds eventually to line 100 where the variable X is also incremented by one. Line 110 then checks if all 21 measurements have taken place. If not, the program returns to line 70 to wait for the next measurement to complete. Now, however, NMEAS=1 and also the variable X=1, and the program again waits for the next measurement when NMEAS will increment by 1 and become 2 at this time. Then, the program continues to line 100 where X is incremented to two and so on until all 21 measurements have taken place.

Another way to write a program to accomplish the same tasks is to use FOR NEXT loops. An example is as follows:

```
 .
 .
 .
40  LAMBDA 500
50  MEASURE 1,1,0,20
```

```
60  FOR X=0 TO 20 STEP 1
70  IF NMEAS=X THEN 70
80    .
90    .
100 NEXT X
 .
 .
 .
```

This program will operate exactly the same as the first example, and in general, using FOR NEXT loops is easier and requires less program lines.

The VALUE( ) Function

The HP 8451 Spectrophotometer will automatically calculate and present the data from a measurement. There may be occasions that arise when either an operation on the data must be performed that is not pre-programmed, or when one wants to output the data in a required format or to increase the speed of operation. It then becomes necessary to be able to access the data from a BASIC program. The VALUE function allows access to either wavelength or time-base measurement values from the result buffer. If the data is invalid or the index is not in the range or list of data stored, the VALUE function returns 9.9E499 as an invalid indicator. For example, to get the value of the data at 340 nm and store it in variable D, the statement is as follows:

```
D = VALUE (340)
```

After executing this statement, the numeric value of the data is stored in variable D. To obtain the value at 28.3 seconds in a time-base series, the statement would be:

```
T = VALUE (28.3)
```

Here are some examples of how to use the VALUE and NMEAS function in BASIC programs.

10 CLEAR	Clear display
20 ERASE STATUS	Reset HP 8451
30 LAMBDA 300 TO 600	Set wavelength range
40 DISP "ENTER SOLVENT - EXECUTE TO CONT";	Display message for solvent blank
50 INPUT A$	Wait for execute
60 REFERENCE	Start reference measurement
70 IF NMEAS = 0 THEN 70	Wait

```
 80  DISP "ENTER SAMPLE - EXECUTE
     TO CONT";

 90  INPUT A$                            Wait for execute

100  MEASURE                             Measure Sample

110  IF NMEAS = 0 THEN 110               Wait for measure to
                                         complete - Auto plot
                                         to CRT

120  REM ** USE VALUE STATEMENT

130  M1 = VALUE (300)                    Initialize min value

140  M2 = M1                             Initialize max value

150  FOR I = 300 TO 600 STEP 2           Loop from 300 to 600 nm

160  M1 = MIN (M1, VALUE (I) )           Check for new min

170  M2 = MAX (M2, VALUE (I) )           Check for new max

180  NEXT I

190  DISP "MINIMUM VALUE ="; M1

200  DISP "MAXIMUM VALUE ="; M2

210  END
```

The HP 8451, with the use of extended absorbance commands, can generate a RESULT. These functions can be ABSORBANCE 500 - ABSORBANCE 600, ABSORBANCE 300 TO 330, or ABSORBANCE 480 - ABSORBANCE 600 TO 640, etc. These types of calculations generate a single-valued number. This calculated answer or RESULT is also accessible with the VALUE( ) function. Example, to get the RESULT of a calculation into Variable R, the statement would be:

```
R = VALUE (-1)
```

Where -1 is used as the index to access that RESULT. The VALUE (-1) command will recover any single valued result (e.g., CONCENTRATION routine result, Absorbance at 500 nm, etc.) for use in a BASIC program. The -1 index is also used during a time-base measurement series to get the value of the most recent measurement.

Time-Based Measurements

In this example, a single wavelength will be monitored versus time. The data will be evaluated after each measurement again using the NMEAS and VALUE functions. If the data at 500 nm is greater than 0.5 absorbance units, the HP 8451 will Beep. The Beep is just to show the decision-making capability of the 8451. Instead of a Beep, the 8451 could actuate a valve, operate a pump, or take an action based on the data from a measurement.

```
10   ERASE STATUS                 !Reset HP 8451 STATUS

20   LAMBDA 500                   !Set WAVELENGTH

30   PRINTER 1                    !Set output to print on CRT

40   MEASURE .2,.2,0,30           !Start MEASURE sequence

50   FOR X=0 TO 150               !Test for 151 measurements

60   IF NMEAS = X THEN 60         !Wait for end of measurement

70   IF VALUE (600) >0.5          !Check if >0.5 and beep
     THEN BEEP 50,50              if true

80   NEXT X

90   END
```

When the above program is run and the measurements are taken, the absorbance at 500 nm is printed on the CRT. If the absorbance is above 0.5 the program will beep. However, there is a problem with this program. Even if the data never exceeds 0.5 absorbance units, after the last measurement the program will beep. This is not a problem with the software but it is an artifact of how time-based measurements work. In a time-base series of measurements (single value or result vs time), the result from each measurement is put into the display buffer and then also put into a time-base buffer. This means that the result of each measurement, either a single wavelength (as in the above example) or result, is available after each measurement. After the last measurement and before returning to the BASIC program, the data from the time-base buffer is moved into both Standard 0 and the results buffer and labeled as time-based data (see Section 4, Time-Based Measurements). Then, when the program resumes to check NMEAS, the data has incremented and then the VALUE (500) is checked. But now the data in the result buffer has limits from 0 to 30, and when the VALUE (500) is executed, the index 500 is not in the range of stored data and returns 9.9E499. This value is greater than 0.5 and the program beeps. There are several methods to avoid this situation. The easiest is to take one more measurement than is required and set up for the next loop to stop before the last measurement. In the above example just changing line 50 to:

```
50   FOR X = 0 TO 149        !Check 150 times
```

This will prevent the inadvertent beep. To check the data of the last measurement at time 30, add the following lines:

```
82   IF NMEAS = 150 THEN 82        !Wait for last measurement

84   IF VALUE(30) >.5 THEN BEEP 50,50
```

STDEV( ) Function

When the integration time of the HP 8451 is one second or greater, the standard deviation of the measurement is also calculated. This statistical information is generally used during the concentration calculation routines. If requested, the standard deviation is accessible in the same fashion as the VALUE function. To get the standard deviation of 340 nm and store it in Variable S, the statement is:

```
S = STDEV (340)
```

The index for time-based data is also the same as VALUE. The index for the standard deviation of a RESULT is -1. Again, an invalid standard deviation or out of range/list index will return a value of 9.9 E499.

The CALCULATE Command

The CALCULATE command is used to execute the current function line with the current display limits (wavelength or time) without sending the information to the output device. This command is useful in a BASIC program when automatically optimizing concentration calculations or changing display limits for best performance. It is also used to execute the function line, but not output, because a special formatted output is required. CALCULATE causes the data processing to be performed on Standard 0 and the answers placed into the results buffer which can then be accessed by the VALUE and other functions. Examples will be shown under the PEAK# function.

The PEAK# Function

The PEAK# ( ) is used with PEAK FIND. Using PEAK# (0), this statement returns the number of peaks found in a spectrum or time-based data. Using PEAK# with an index from 1 to 20 will return the wavelength or time axis where the peak was found. If the index is greater than the number of peaks that were found, the function generates error 89: INVALID PARAM.

Here is an example using PEAK FIND, CALCULATE and PEAK# commands in a program:

```
      .
      .
      .

70  PEAK FIND
```

```
80  CALCULATE

90  FOR X = 1 TO PEAK#(0)

100  PRINT X;PEAK#(X);VALUE (PEAK#(X) )

110  NEXT X

    .
    .
    .
```

Assuming PEAK FIND found four peaks at 240 nm, 260 nm, 310 nm and 400 nm, the above program would print out a table with absorbance or transmittance values:

```
1  240    1.2345

2  260    0.6789

3  310    0.0123

4  400    0.4567
```

CONCENTRATION Results

With the built-in capability of the HP 8451 to calculate concentration using both single and multi-component techniques, the results of these calculations are also available to the BASIC programs with simple functions. These statements are:

RELFITERR	Returns the value of the relative fit error for maximum likelihood method or standard fit error for the least squares methods.
INDEPSTD	Returns the value of independence of standards.
MULTICONC (Std #)	Returns the concentration of the unknown corresponding to Std #, in a multicomponent analysis.
MULTIDEV (Std #)	Returns the value of the relative standard deviation of the unknown corresponding to Std #, in a multi-component analysis.
STATCONCK (0 to 2)	Returns the values of K0, K1, K2 constants determined for a particular calibration curve, using 0 (y-intercept), 1 (slope), and 2 (curvature), respectively.
STATCONCKDEV (0 to 2)	Returns the standard deviation of K0, K1, or K2.

STATCONCABS (Std #)	Returns the value of the absorbance of the standard corresponding to STD #, used for single component analysis.
STATCONC (Std #)	Returns the value of the concentration of the standard corresponding to Std #.
STATCONCERR (Std #)	Returns the % error difference between the standard corresponding to Std # and the calculated concentration curve.

```
     multicomponent analysis
relative fit error       18.2785   RELFITERR
independence of stds     42.2755   INDEPSTD
STD      CONC            std dev
1         4.79141        .002      MULTIDEV (1)
2         3.53031        .01
3         5.42674        .014
4         5.12877        .003      MULTIDEV (4)
                                   MULTICONC (4)
```

Figure 8-2. Typical Output of Multicomponent Analysis Results

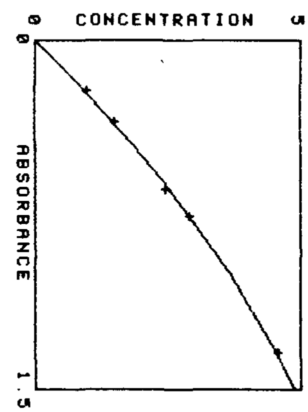
```
     STATUS CONCENTRATION 0        STATCONCK (2)
  K0= 3
  K1= 23.5779
  K2= 0                            STATCONCABS (11)
STD    ABS        CONC      % ERR
11   .172714     3.938      -3.3
12   .326003     7.876       2.5   STATCONCERR (12)
13   .504085    11.814       -.6
14   .651807    15.752       2.5
15   .833134    19.69        -.5
                                   STATCONC (15)
```

Figure 8-3. Typical Output of Single Component Analysis Results Using Concentration Method 0.

The following program is an example of how to use some of these functions to generate a Beer's Law plot (concentration versus absorbance). The program will ask which concentration procedure (0 to 3) should be used to calculate a calibration curve, print out the Status Concentration Table, and then generate a Beer's Law plot.

The Beer's Law plot (concentration vs absorbance)

```
   STATUS CONCENTRATION 2
  K0= 0
  K1= 4.44545
  K2= -.78698
STD   ABS         CONC        % ERR
1    .224548     1               4.3
2    .363281     1.52307          .8
3    .651794     2.5            -2.5
4    .766998     2.93461         -.4
5    1.34889     4.60769          .9
```




```
10 REM *** STATUS CONCENTRATION
20 REM *** DEMO BEER'S LAW PLOT
30 REM *** REQUIRES PRINTER/
40 REM *** PLOTTER ROM
50 ALPHA
60 PRINTER 2
70 PLOTTER IS 1
80 DISP "ENTER CONC#";
90 INPUT C
100 IF C>3 OR C<0 THEN 80
110 CONCENTRATION C,1,2,3,4,5
120 STATUS CONCENTRATION
130 LOCATE 15,120,15,95
140 SCALE 0,1.5,0,5
150 GCLEAR
160 FRAME
170 DEG @ LDIR 0
180 MOVE 0,-.1 @ LORG 6 @ LABEL
    "0"
190 MOVE 0,0 @ LORG 8 @ LABEL "0
    "
200 MOVE 0,5 @ LORG 8 @ LABEL "5
    "
210 MOVE 1.5,-.1 @ LORG 6 @ LABE
    L "1.5"
220 MOVE .75,-.1 @ LORG 6 @ LABE
    L "ABSORBANCE"
230 MOVE -.05,2.5 @ LDIR 90 @ LO
    RG 4 @ LABEL "CONCENTRATION"
240 K0=STATCONCK(0)
250 K1=STATCONCK(1)
260 K2=STATCONCK(2)
270 FOR X=0 TO 1.5 STEP .1
280 Y=K0+K1*X+K2*X^2
290 PLOT X,Y
300 NEXT X
310 PENUP
320 FOR X=1 TO 5
330 MOVE STATCONCABS(X),STATCONC
    (X)
340 LORG 5
350 LABEL "+"
360 NEXT X
370 END
```

COMMANDS FOR AUTO SAMPLER AND PERISTALTIC PUMP

(Advanced Techniques Module)

There are specific commands for operating the autosampler and peristaltic pump that allow the user to customize an automated sample analysis. These commands require the Advanced Techniques Module (HP 89050A), Sipper/Sampler Interface (HP 89053A), and any one of the following ROMS:

1. MASS STORAGE

2. I/O

3. PRINTER/PLOTTER

The HP 89072 Autosampler is recommended for use with the HP 8451 Spectrophotometer. The sampler commands are interactive with the sampler and will wait for the function to complete before the program will proceed. The commands are:

Commands	Action
TRAY ADVANCE	Move sampler to next position. If probe is down, the probe will rise first. Will not index past last sample position.
PROBE DOWN	Lowers probe. If already down, nothing happens.
PROBE UP	Raises probe. If already up, nothing happens.
PUMP OFF	Stops pump.
PUMP ON [n]	Starts pump. With no parameter or positive parameter, pump turns clockwise; with negative parameter, pump turns counterclockwise. This is useful for returning the sample after measurement.
SAMPLE POSITION	Moves probe over test tube rack. If probe already there, nothing happens. If probe down, the probe will rise first.
WASH POSITION	Moves probe over optional wash station. If probe already there, nothing happens. If probe down, the probe will rise first.
TRAY START	Moves tray to one position past lock sample indicator.

Here is an example of a program to operate the autosampler. This program will ask the operator to enter the wavelength, concentration of the standard, and the number of samples to be run. The sequence of the tray is a blank for a REFERENCE measurement, a STANDARD, and then the number of samples to measure.

10 ERASE STATUS	Reset HP 8451
20 ERASE STANDARD 1	-
30 CLEAR	Clear CRT
40 DISP "ENTER WAVELENGTH";	Ask for wavelength
50 INPUT L	-
60 LAMBDA L	Set wavelength

70 DISP "ENTER CONC. OF STANDARD";	Ask for standard concentration
80 INPUT C	-
90 DISP "ENTER # OF SAMPLES";	Get number of samples
100 INPUT N	-
110 DISP "MOVE TRAY TO BLANK"	-
120 DISP "THEN PRESS EXECUTE TO START";	Wait for operator to press EXECUTE
130 INPUT A$	-
140 GOSUB 350	Get blank for reference
150 REFERENCE	Start reference
160 IF NMEAS=0 THEN 160	Wait for reference
170 GOSUB 430	Subroutine to discard sample
180 PRINT "CONC. OF STANDARD=";C	Print standard info
190 GOSUB 350	Get standard
200 MEASURE	Measure standard
210 If NMEAS=0 THEN 210	Wait for measure
220 TO STANDARD 1,C	Store standard with conc.
230 GOSUB 430	Discard standard
240 MODE 0,1	Turn output off
250 CONCENTRATION 0,1	Set concentration routine
260 PRINT " # CONCENTRATION "	Print title
270 FOR I=1 TO N	For, next loop for "N" samples
280 GOSUB 350	Get sample
290 MEASURE	Measure and calculate conc.

300 IF NMEAS=0 THEN 300	Wait for measure
310 PRINT I;VALUE(L)	Print sample # and conc.
320 GOSUB 430	Discard sample
330 NEXT I	Do all samples
340 END	End of program
350 REM *** GET SAMPLE ***	
360 SAMPLE POSITION	
370 PROBE DOWN	
380 PUMP ON	Subroutine to get sample from tube into flow cell
390 WAIT 5000	
400 PUMP OFF	
410 PROBE UP	
420 RETURN	
430 REM ** DISCARD SAMPLE ***	
440 PUMP ON	Subroutine to discard samples and to advance tray.
450 TRAY ADVANCE	
460 WAIT 3000	
470 PUMP OFF	
480 RETURN	

Here is a sample of an output for this program where the wavelength is 550 nm, concentration of the standard = 100, and ten samples.

```
CONC. OF STANDARD= 100
550= .261108
 #   CONCENTRATION
 1   100.034
 2   100.07
 3   100.04
 4   100.059
 5   100.04
 6   100.052
 7   100.07
 8   100.005
 9   100.152
 10   100.064
```

STOP MEASURE Command

The STOP MEASURE command will stop a measurement sequence that is in progress. If it happens to be a time-based sequence, this command will not only stop the measurement, but also save the information as time data with correct start and end times. Here is an example of a kinetic measurement where we are checking the absorbance for a change that exceeds 0.3 from the first measurement.

```
10   ERASE STATUS               !Reset HP 8451
20   LAMBDA 340                 !Set wavelength
30   Y-SCALE 0 TO 1             !Set Y-Scale
40   MEASURE 1,1,0,300          !Start measurement
50   FOR X=0 TO 300             -
60   IF NMEAS=X THEN 60         !Wait for each measurement
70   IF X=0 THEN                !If 1st measure save start absorbance
     D=VALUE(340)
80   IF VALUE (340)
     >D+.3 THEN 100             !  ABSORBANCE >0.3?
90   NEXT X                     !Get next measure
100  STOP MEASURE               !
110  PRINT "TIME OF
     MEASUREMENT=";X;"SECS" -
120  END
```

The measurements will proceed until either the absorbance change is greater than 0.3 or the total time of 300 seconds has been reached.

ON MEASURE, OFF MEASURE Commands

As previously stated, the HP 8451 can be taking measurements while a BASIC program is running. This allows the capability of starting a measurement sequence and have the program performing a totally unrelated task. The ON MEASURE command, when executed, will interrupt the BASIC program at the end of a program line and either GOTO or GOSUB to a different part of the program. The two different forms of the command are:

ON MEASURE GOTO line #

or

ON MEASURE GOSUB line #

The ON MEASURE command is active until, SCRATCH or STOP or RESET is pressed, or an OFF MEASURE statement is declared.

In this example, the program will start a measurement sequence where a measurement of four wavelengths will take place at 30 second intervals. At that time, the ratio's of wavelength 1 to the other 8 will be printed. In addition, when the HP 8451 is not busy with the data from the measurements, it will be plotting a SIN curve onto the CRT (you can substitute your application in this example).

```
 10  ERASE STATUS              !Reset HP 8451

 20  LAMBDA 250,276,290,316    !Set four wavelengths

 30  MODE 0,1                  !Output off

 40  ON MEASURE GOSUB 140      !Enable ON MEASURE

 50  MEASURE 1,30,0,300        !Start measurement sequence

 60  DEG                       !Angle in degrees

 70  PLOTTER IS 1              !Define plotter (CRT)

 80  GCLEAR                    !Clear CRT graphics

 90  SCALE 0,260,-1,1          !Set CRT scaling

100  FOR X=0 TO 360 STEP 5     !Plot SIN wave on CRT

110  PLOT X, SIN (X)           -

120  NEXT X                    -

130  IF NMEAS=11 THEN 200
     ELSE 60                   !Check if done

140  PRINT "MEASURE #";
     NMEAS                     !After each measure

150  PRINT "  250/316=";
     VALUE (250)/VALUE (316)   !Program executes

160  PRINT " 276/316=";
   VALUE (276)/VALUE (316)     !Lines 140 to 190
```

```
170  PRINT " 280/316=;
       VALUE (290)/VALUE (316)

180  PRINT

190  RETURN

200  OFF MEASURE

210  PRINT "DONE"

220  END
```

STORING AND RUNNING BASIC PROGRAMS

There are two methods to store and run BASIC programs. First, with the alphanumeric keyboard, you can store the program with a name from 1 to 10 characters in the form:

STORE " name 1 to 10 chars "

To run a program stored in this form, the operator must first LOAD and then RUN the program. Refer to the MASS STORAGE ROM Manual for details.

The second form in which to store programs allows the programs to be loaded and run without the alphanumeric keyboard. Simply store the program in the format:

STORE " PGM number "

space

Where: the number is between 1 to 32767.

Then, to run the program, simply press the RUN PROGRAM key on the functional keyboard followed by the number and then EXECUTE. The program will be loaded and then run in one operation.

Autostart

The HP 8451 can automatically load and run a program from a disc when the power is turned on. The following conditions must exist for the autostart:

1. Advanced Techniques Module installed
2. Mass Storage ROM installed
3. HP-IB Interface installed
4. Disc drive attached and power ON

5. Disc installed

6. The service ROM must not be installed.

7. A user program on the disc is named "Autost". Such a program could print "Good morning" on the printer or begin an analysis procedure.

MEMORY Commands

There are occasions when it necessary to measure and store data very rapidly. Normally, one can do this by storing the data into standards as follows:

```
          :
 40 LAMBDA 250 TO 420
 50 ABSORBANCE
 60 MEASURE 1,1,1,60
 70 FOR N=1 TO 60
 80 IF NMEAS<N THEN 80
 90 TO STANDARD N
100 NEXT N
          :
```

Notice the use of variable N for the standard number in line 90. Now, while this works very well, the problem with using standards for storage is that there is limited space available. Storing data to disc files solves the space limitation problem, but writing to the disc requires more time. This leads to the utility of the MEMORY commands. Here we have the best of both worlds. With the addition of extra memory, up to four 128K modules, the HP 8451A can save a large amount of data very rapidly. In fact, in the above example, with the wavelength range set to 250 to 420 nm, just one 128k Memory Module can store over 160 measurements.

TO MEMORY Command

The TO MEMORY command is used in the same manner as the TO FILE command (refer to Section 5 for details). The general form of the command is:

TO MEMORY n

where n is location number from 0 to 4999.

To change the above program to use the TO MEMORY command, simply change line 90 to:

```
90 TO MEMORY n
```

RECALL MEMORY Commands

When the RECALL MEMORY command is executed, the data stored in the location specified by the number will be moved from the 128k Memory Modules to both standard 0 and the Result buffer. The general form of the command is:

```
RECALL MEMORY n
```

where n = location number from 0 to 4999.

Now, as an example of the RECALL MEMORY command, let us assume that the program above was run, and 60 spectra from 250 to 420 nm are stored in the extra memory. The next section of the program will ask the operator to enter the wavelength of interest and the Y-scale desired, and then recall each spectra and extract the value at that wavelength and plot it vs. time. That section of the program might look like this:

```
180 CLEAR                        !Clear CRT
190 DISP "ENTER λ";              !Ask for wavelength
200 INPUT W                      !Operator input
210 DISP "ENTER YMIN,YMAX";      !Ask for YMIN and YMAX
220 INPUT Y1,Y2                  !Operator input
230 GCLEAR                       !Clear graphics screen
240 SCALE 1,60,Y1,Y2             !Scaling for plot
250 FOR N=1 TO 60                !For next loop
260 RECALL MEMORY N              !Recall memory location
270 PLOT N, VALUE (W)            !Plot INDEX and VALUE at a
280 NEXT N                       !Repeat until done
```

ERASE MEMORY Command

The ERASE MEMORY command is used to either erase a single location or the entire contents on the extra memory. The general form of the command is:

```
ERASE MEMORY n
```

where n = location number from 0 to 4999, or
n = -1 to erase entire contents of memory

To erase location 17 in the extra memory, the command would be:

```
ERASE MEMORY 17
```

To erase the entire memory, the command would be:

```
ERASE MEMORY -1
```

To erase a range of locations, you can use a FOR NEXT loop:

```
    .
    .
    .

70 FOR L = 27 to 33

80 ERASE MEMORY L

90 NEXT L

    .
    .
    .
```

It is important to note that the files are stored in memory in storage sequence and not in numerical sequence. After an ERASE MEMORY command, if the location that is erased is in the middle of the memory area, the remaining data is packed. This packing takes a fair amount of time if a large number of files are stored. If the location that is being erased was the last one stored, the packing procedure does not take place. This will speed up operation. For example, if in the above program, location 33 was the last file stored, it would run faster if written as follows:

```
    .
    .
    .
70 FOR L = 33 TO 27 STEP -1

80 ERASE MEMORY L
```

```
90 NEXT L
     .
     .
     .
```

STATUS MEMORY( ) Function

The STATUS MEMORY ( ) function is used to determine the amount of available memory left in the extra memory. To display the available external memory simply type in:

```
STATUS MEMORY (0)
```

The STATUS MEMORY function can also be used to perform a self-test of the entire extra memory. To execute a self-test and display the results, type in:

```
STATUS MEMORY (1)
```

and if the self-test is successful the value returned is 0. If an error has occurred then a non-zero number is returned.

MAINTENANCE

INTRODUCTION

The HP 8451 is designed to require minimum maintenance. Its fixed grating and diode array detector are essentially maintenance free, and the instrument contains only three moving parts (the shutter, printer assembly, and a cooling fan).

This section describes the routine maintenance tasks which should be performed by the user, and the diagnostics functions which are used to characterize the instrument.

ROUTINE MAINTENANCE

The routine maintenance required involves replacing the deuterium lamp, replacing the air filter, and cleaning exposed surfaces of the optical system. These tasks are summarized in Table 9-1 which also shows the recommended interval and typical lifetime of the lamp. Table 9-2 shows the required equipment.

TABLE 9-1. USER MAINTENANCE TASKS

Maintenance Task	Interval or Lifetime	HP Part No.
Lamp, Replace	1000 hours (1/2 life)	08451-60100
Air Filter, Replace	6 months	3150-0461
Optical Surfaces, Clean	1 week or as required	-

TABLE 9-2. EQUIPMENT

Item	Supplier
Screwdriver, Flatblade	Any
Camera Lens Cleaning Tissue	Kodak HP Part No. 9300-0761
Isopropanol	Any

Lamp Replacement

The deuterium lamp (HP Part No. 08451-60100) provides radiation in the 190-820 nm range from a plasma discharge in low pressure deuterium gas inside a quartz envelope.

Due to a variety of factors, including the sputtering of anode metals on the quartz and outgassing of the lamp elements, the radiation intensity gradually decreases during use. It generally does not fail abruptly (burn-out) but its output will typically drop to one-half its original level in about 1000 hours.

The built-in diagnostics, active during turn-on of the instrument, check the intensity of the return radiation to the spectrograph and display an appropriate warning message if it falls below minimum levels. If the message "Warning 108: OPTICAL SYSTEM - E" occurs, ensure that beam path is clear of sample, etc., check all optical surfaces for cleanliness and refer to User Callable Diagnostic, INTENSITY, to check the lamp output. The lamp may be used beyond this time but measurement accuracy may be impaired; i.e., more "noisy" data may be obtained as evidenced by a larger standard deviation for datapoints.

To replace the UV lamp, proceed as follows:

1. Turn off power to the instrument and disconnect the power cord from the outlet. Allow the lamp to cool at least one half hour.

WARNING

Lamps can become very hot and cause injury. Replace only when cool.

2. Lift the sample compartment cover.

3. Locate and loosen the two screws holding the lamp compartment cover in place (see Figure 9-1).

4. Carefully withdraw the lamp compartment cover. The cover has a long post attached to the front right corner that must be guided straight upwards when removing the cover.

5. Disconnect the lamp power plug (see Figure 9-2).

6. Remove the two lamp hold-down screws.

7. Grasp the lamp by the metal base (do not pull on the wires!) and carefully lift it off of the alignment pin (a slight wiggling motion will help).

8. Turn the lamp 180 degrees such that the tube protruding from the lamp is aligned with the hole in the lamp compartment (see Figure 9-3).

9. Carefully withdraw the lamp.

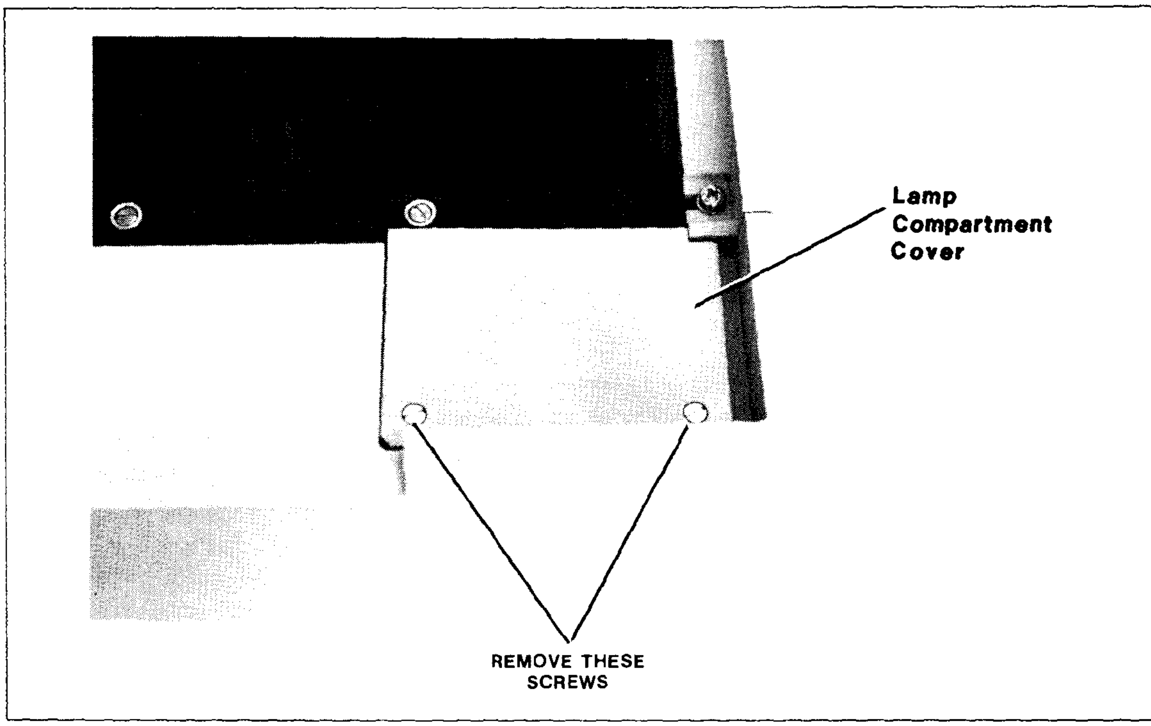


Figure 9-1. Lamp Compartment Cover

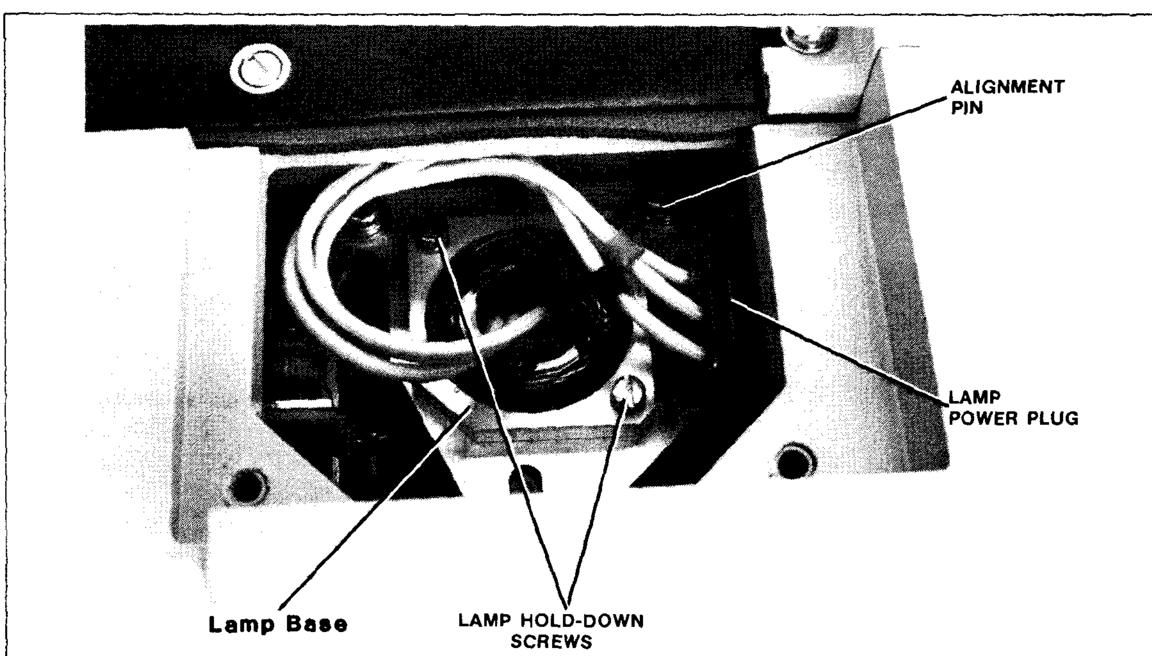


Figure 9-2. Lamp Location

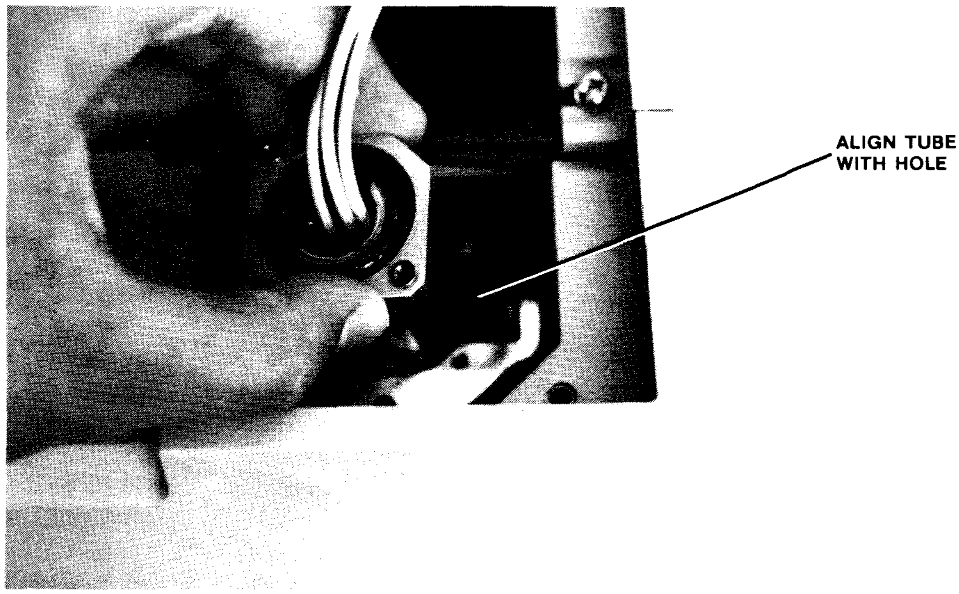


Figure 9-3. Removing Lamp

10. Carefully unwrap the new lamp taking care not to touch the quartz envelope (oils from fingerprints absorb strongly in the UV region). When in doubt, clean the quartz envelope with Kodak camera lens cleaning tissues and reagent grade isopropanol.

11. Carefully insert the new lamp, turn it 180 degrees, and position the alignment cutout in the base assembly over the alignment pin. The lamp should fit without force exerted.

12. Reinstall the two mounting screws and reconnect the electrical plug.

13. Note the replacement date on an adhesive label and affix it to a nearby surface.

14. Replace the lamp compartment cover taking care to insert the long rod in the correct position.

AIR FILTER REPLACEMENT

The air filter element (HP Part No. 3150-0461) is located underneath the instrument and is accessed as follows:

1. Turn off power to the instrument and disconnect the power cord from the outlet.

2. Turn the instrument up on its back panel to expose the air filter.

3. Push the air filter downwards (towards the back panel of the instrument) and then pull the top of the filter out towards you to remove.

4. Insert a new filter, orienting the filter such that the arrow indicating air flow direction points towards the interior of the spectrophotometer.

5. Return the instrument to its upright position.

OPTICAL SURFACE CLEANING

All exterior optical surfaces must be kept scrupulously clean since they must pass wide bandwidth radiation. The exterior optical surfaces are shown in Figure 9-4.

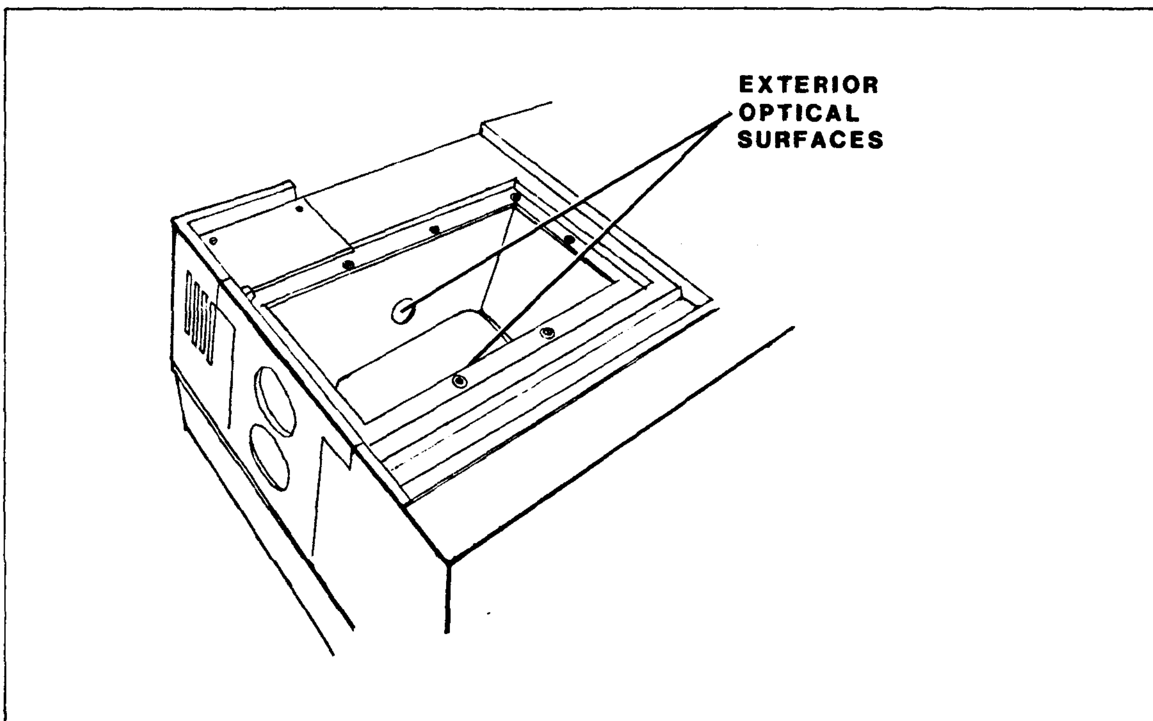


Figure 9-4. Exterior Optical Surfaces

The built-in system diagnostics check light levels at power turn-on. If insufficient intensity is detected, a message such as "Warning 108: OPTICAL SYSTEM - E" appears on the display. This is usually due to low output from the lamp or to dirty optical surfaces in the light path.

Clean exterior surfaces as follows:

1. Dust off any particulate matter with a small, soft artist's brush or with a can of compressed gas designed for this purpose.

2. Wipe all exterior surfaces with a tissue moistened with reagent grade isopropanol.

3. Wipe surfaces with clean, dry tissue.

4. Repeat steps 2 and 3 with fresh tissue if necessary.

CAUTION

Do not use tissues designed for cleaning eye glasses, since polishing and lubricating compounds in them will coat optical surfaces and impair performance. Use only tissues for cleaning camera lenses. Kodak Lens Tissue is such a product.

CAUTION

Do not attempt to clean any internal optical surfaces (mirrors). Permanent damage may result.

DIAGNOSTICS

Overview

To verify proper system operation and to aid service personnel in locating problems, an extensive set of internal diagnostics has been included in the HP 8451. At turn-on a series of diagnostics verify proper hardware operation. First, core parts are tested, and then the core is expanded and tested. Once the turn-on sequence has been completed many of these diagnostics and other more comprehensive tests not done at turn-on may performed by the user. In addition, some of these tests are run continuously during system operation to provide on-going fault checks.

When a failure occurs the internal diagnostics provide feedback in several ways. Many of the tests will display/print a descriptive error message on the CRT/Printer. Additional information can be gained through a set of labeled LEDs on the front panel. Proper use of these internal diagnostics helps to reduce the time spent on isolation of the problem.

Measurement Processor Turn-On Diagnostics

When power is applied to the instrument, fourteen tests are automatically performed to ensure proper operation of the Measurement Processor system and the measurement hardware.

Failure of tests 2-5 will disable the instrument. The CPU will attempt to flash an error code on the front panel LEDs.

Failure of tests 6-8 will prevent the instrument from functioning as a spectrophotometer. An error message will be displayed on the CRT and the four LEDs will flash; but the instrument can still perform as an HP 85 computer.

Failure of tests 9 or 11 will prevent the instrument from functioning as a spectrophotometer. An error message will be displayed on the CRT and the four LEDs will flash. At this point, the instrument can still perform as an HP 85. If the lamp is already lit, a "lamp" command will restart the tests without going through the lamp lighting procedure.

Failure of tests 10 and 12-14 may still permit the instrument to be useful as a spectrophotometer but impaired specifications may result. Only a warning is given and the instrument is ready for use.

1. LED Test

The LEDs on the front panel (with the exception of "power") flash briefly.

2. CPU Test

Several of the more difficult instructions for the Measurement Processor are executed and the results checked. If the test fails, the "LAMP" LED will flash.

3. ROM Test

The checksum is computed for the ROM and compared with the checksum stored in the ROM. If the test fails, the "DIAGNOSTIC" LED will flash.

4. RAM Test

A series of eighteen patterns are written into RAM. After each pattern, the RAM is read and the contents compared with that pattern. The bits in error are indicated by the pattern of flashing LEDs. Bits 0 through 7 correspond to RAM chips U3 to U10 on the Z80 Measurement Processor Board (HP Part No. 08451-60011).

Bit in Error	MEASURING	PGM RUNNING	DIAGNOSTICS	LAMP
0	0	1	1	0
1	0	1	1	1
2	1	0	0	0
3	1	0	0	1
4	1	0	1	0
5	1	1	0	1
6	1	1	0	0
7	1	1	1	1
Multiple	1	1	1	0

Note: "1" = LED Flashing; "0" = LED off

5. DMA Test

Two 16-bit words and their complements are exchanged between the Measurement and HP 85 Processors via DMA. The "PGM RUNNING" LED will flash until the Measurement Processor establishes communication with the HP 85 processor. If this failure occurs, first check that the personality module is installed.

6. Hardware Multiplier Test

A sequence of 250 pairs of numbers is used to test 8-bit unsigned multiplication. If there is an error, the lower four LEDs will flash and "ERROR 113: MEASURE SYSTEM" will be displayed on the CRT. The letter "S" will precede the error message.

7. Timer-Interrupt Test

The hardware timer-interrupt is checked using a software timing loop. If there is an error, the lower four LEDs will flash and "ERROR 113: MEASURE SYSTEM" will be displayed on the CRT. The letter "T" corresponds to problems with the timer and maskable interrupt; and the letter "V" to problems with the non-maskable interrupt.

8. Lamp

If there is a problem turning on the lamp, the four LEDs will flash and "ERROR 109: LAMP" will be displayed. A "LAMP" command is necessary to retry the lamp turn-on.

9. ADC and Analog-Reference Test

An Analog to Digital conversion is performed on the analog-reference voltage. If the result falls outside of a given threshold level, the four LEDs will flash and "WARNING 108: OPTICAL SYSTEM" will be displayed. The letter "F" will follow the message. A "LAMP" command is necessary to retry the test without turning off the lamp.

10. Leaky Diodes Test

If the "DARK" reading at gain 0 is above a given threshold for any diode, "WARNING 108: OPTICAL SYSTEM" will be displayed. The letter "A" follows the message. The Measurement Processor continues with the next test.

11. Average Light Level Test

If the difference between the "LIGHT" and "DARK" signals averaged over all diodes at gain 0 falls below a given threshold, the four LEDs will flash and "WARNING 108: OPTICAL SYSTEM" with the letter "B" following will be displayed. A "LAMP" command is necessary to restart all the optical tests without turning off the lamp.

12. Gain Amplifier Test

The Gain Amplifier is checked. If there is an error, "WARNING 108: OPTICAL SYSTEM" followed by "C" is displayed. The Z80 continues with the next test.

13. Gain Leveling Test

If any diode cannot be adjusted below the saturation level, "WARNING 108: OPTICAL SYSTEM" followed by "D" is reported. The Z80 continues with the next test.

14. Dark Adjusted Intensity Test

For each diode, a minimum intensity after gain leveling is required. If there is an error, "WARNING 108: OPTICAL SYSTEM" followed by "E" is reported.

TABLE 9-3. SUMMARY OF MEASUREMENT PROCESSOR TURN-ON DIAGNOSTICS

Status or Error Message Displayed	Test	Error Label
-	LED	
System idle, "LAMP" LED flashing	CPU	
System idle, "DIAGNOSTIC" LED flashing	ROM	
System idle, LEDs flashing	RAM	
System idle, "PGM RUNNING" LED flashing	DMA	
4 LEDs flashing, Error 113: MEASURE SYSTEM	Multiplier	S
4 LEDs flashing, ERROR 113: MEASURE SYSTEM	Timer-Interrupt	T,V
4 LEDs flashing, * ERROR 109: LAMP	Lamp	
4 LEDs flashing ** WARNING 108: OPTICAL SYSTEM	ADC and Analog Subtract	F
WARNING 108: OPTICAL SYSTEM	Leaky Diodes	A
4 LEDs flashing ** WARNING 108: OPTICAL SYSTEM	Aver. Light Level	B
WARNING 108: OPTICAL SYSTEM	Gain Amplifier	C
WARNING 108: OPTICAL SYSTEM	Gain Leveling	D
WARNING 108: OPTICAL SYSTEM	Dark Adjusted Intensity	E

* A "LAMP" command is necessary to reinitiate the lamp turn-on procedure.

** If the lamp is already lit, a "LAMP" command will restart all the optical tests without going through the lamp turn-on procedure.

HP 85 Turn-On Diagnostics

Self-Test

The HP 85 system performs a simplified ROM test, RAM test, printer test and keyboard test. The CPU, CRT and timers are not checked. If a problem is found, the system beeps twice and the message "ERROR 23: SELF TEST" is displayed. This may also indicate a missing or bad personality module.

I/O Modules

The I/O modules perform self-test and interrupt the CPU to report the results. At turn-on, the CPU logs the interrupting cards into the select code table (regardless of the self-test pass/fail results). If there is a failure, "ERROR 110" is displayed.

Measurement Processor Handshake

Two 16-bit words and their complements are exchanged between the two processors via DMA. The HP 85 processor will be tied-up until the handshake is successful.

Diagnostics During Operation

Lamp

If there are problems turning on or off the lamp, "ERROR 109: LAMP" will be displayed.

If the lamp cover is removed while the lamp is lit, "ERROR 109: LAMP" will be displayed and the lamp will go out.

Measurement Processor - HP 85 Communication

If a Measurement Processor DMA request is not acknowledged within 15 milliseconds, the "PGM RUNNING" LED will flash until the request is acknowledged. This can occur if another I/O processor has control of the bus.

LED Indicators

A series of LED indicators has been included on the front panel and inside the HP 8451 to display status and assist field personnel in diagnosing system failures. They are labeled as to their function and are mounted in easily visible locations. These indicators can be used to gain information in addition to the other built-in diagnostics. But their main use comes when these other diagnostics are unable to convey the information.

NOTE

LED indicators inside the HP 8451 are not intended for the instrument user. Only trained service personnel should open the instrument.

Motherboard PCA

24V	(RED)	POWER SUPPLY STATUS
+12H	(RED)	POWER SUPPLY STATUS
+6V	(RED)	POWER SUPPLY STATUS
+12L	(RED)	POWER SUPPLY STATUS
-12V	(RED)	POWER SUPPLY STATUS
+5V	(RED)	POWER SUPPLY STATUS

Secondary Power Supply PCA

SHUTTER	(RED)	Shutter is open

Measurement Processor PCA

PON	(GREEN)	+5,+6,+12L supplies are adequate
CLOCK (2)	(AMBER)	Clock is running if both are lit
STATUS	(RED)	Outside of interrupt processing

HP 85 PCA

HALT	(AMBER)	HP 85 Processor is halted by Measurement Processor
WAIT	(AMBER)	During DMA Xfers, Measurement Processor wait states are inserted until control signals are latched

Front Panel

POWER	(AMBER)	Same as PON on Measurement Processor PCA
MEASURING	(AMBER)	Measurement Processor is busy
PGM RUNNING	(AMBER)	Basic program is running or data being processed
DIAGNOSTIC	(AMBER)	Diagnostic running
LAMP	(AMBER)	Lamp is lit

User-Callable Diagnostics

Once the HP 8451 has completed the turn-on sequence, more extensive diagnostics can be accessed through BASIC commands. Many of these same tests are performed automatically in the turn-on diagnostics sequence, but they are run only once during that time. After turn-on they can be called up individually and run for long periods of time, exercising the system continuously to help isolate intermittent failures. Other diagnostics not performed during the turn-on sequence can also be run.

DIAGNOSTIC 0 - LED Test

What it does:

This test flashes the front panel LEDs one at a time starting with the "LAMP" LED. Each LED stays "ON" for about 1/2 second. This test performs no internal checks. The "POWER" LED is not affected by this test. It remains "ON" provided the +5V, +6V, and +12L supplies are at adequate levels.

How to run it:

To run the LEDs test, enter "DIAGNOSTIC 0, m" where m = number of repetitions, 1 to 32767.

Results:

After the diagnostic is selected, the message "LED TEST" is printed. After flashing each LED in turn, the message "END TEST" is printed.

DIANOGSTIC 1 - Measurement Processor CPU Test

What it does:

Several of the more difficult instructions for the Z80 microprocessor are executed and the results checked. Most of the CPU must be OK in order to acknowledge the command to run this test. Hence, this test checks only a portion of the CPU.

How to run it:

To run the Z80 CPU test, enter "DIAGNOSTIC 1, m" where m = number of repetitions, 1 to 32767.

Results:

After the diagnostic is selected, the message "MEASURE CPU TEST" is printed. If any errors are found, the number of tests which failed is reported. The message "END TEST" follows.

DIAGNOSTIC 2 - Measurement Processor ROM Test

What it does:

The checksum is computed for the ROM and compared with the checksum stored in the ROM.

How to run it:

To run the Z80 ROM test, enter "DIAGNOSTIC 2, m" where m = number of repetitions, 1 to 32767.

Results:

After the diagnostic is selected, the message, "MEASURE ROM TEST" is printed. If any errors are found, the number of tests which failed is reported. The message "END TEST" follows.

DIAGNOSTIC 3 - Measurement Processor RAM Test

What it does:

A series of 18 patterns is written into RAM. After each pattern, the RAM is read and the contents compared with that pattern. This test takes about 19 seconds to complete. **CAUTION!!! This test results in loss of reference data.**

How to run it:

To run the Z80 RAM test, enter "DIAGNOSTIC 3, m" where m = number of repetitions, 1 to 32767.

Results:

After the diagnostic is selected, the message "MEASURE RAM TEST" is printed. Only the last failure detected is reported after each test. The bit in error is printed, or if there is more than one bit in error "BIT 8" is reported. There is a beep after each test. After all the tests are run, the number of tests which failed is printed. The message "END TEST" follows.

DIAGNOSTIC 4 - DMA Test

What it does:

The HP 85 processor places eight bytes of data in the memory. The Z80 reads the memory via DMA and sends the complement of the data back. The HP 85 processor then verifies the data.

How to run it:

To run the DMA test, enter "DIAGNOSTIC 4, m" where m = number of repetitions, 1 to 32767.

Results:

After the diagnostic is selected, the message "DMA TEST" is printed. If any errors are found, the number of tests which failed is reported. The message "END TEST" follows.

If the Z80s DMA requests go unacknowledged, then the "PGM RUNNING" LED flashes.

DIAGNOSTIC 5 - Hardware Multiplier Test

What it does:

A sequence of 250 pairs of numbers is used to test the 8-bit hardware multiplier. The unsigned 8-bit multiplications are performed in software and compared to the hardware results. **CAUTION!!! This test results in loss of reference data.**

How to run it:

To run the multiplier test, enter "DIAGNOSTIC 5, m" where m = number of repetitions, 1 to 32767.

Results:

After the diagnostic is selected, the message "MULTIPLIER TEST" is printed. If an error is found, the test quits and prints the multiplicand, multiplier and the incorrect hardware result. After all the tests are run, the number of tests which failed is reported. The message "END TEST" follows.

DIAGNOSTIC 6 - Timer-Interrupt Test

What it does:

The timers are programmed as they would be for normal operation. The timer registers are loaded and after a given period of time (determined by software timing) checked for proper values. The interrupt is then enabled and after a waiting period (again, using software timing) a check is made for interrupts generated by timers 0 and 1 to have occurred 1 microsecond apart. **CAUTION!!! This test results in loss of reference data.**

How to run it:

To run the timer-interrupt test, enter "DIAGNOSTIC 6, m" where m = number of repetitions, 1 to 32767.

Results:

After the diagnostic is selected, the message "TIMER-INT. TEST" is printed. If an error is found, then "TIMER ERROR" or "INTERRUPT ERROR" is reported. After all the tests are run, the number of tests which failed is printed. The message "END TEST" follows.

DIAGNOSTIC 7 - HP 85 System ROM and RAM

What it does:

This test checks the RAM Controller and RAM integrated circuits by writing a checkerboard into the RAM and then reading it to see if the contents have been changed. The ROMs are checked by computing their checksums and comparing them with those stored in the ROMs. To check the printer controller chip, a byte is read from the printer character ROM. To check the keyboard controller chip, a status byte is read. To check RAM refresh, eight bytes of data are read and compared with the data stored earlier.

How to run it:

To run the system RAM and ROM test, enter "DIAGNOSTIC 7, m" where m = number of repetitions, 1 to 32767.

Results:

After the diagnostic is selected, the message "SYSTEM RAM, ROM TEST" is printed. There is a beep after each test. If any error is found, "ERROR n" is printed where

n = 0 RAM CHECKERBOARD ERROR
= 1 ROM 0 CHECKSUM ERROR
= 2 ROM 1 CHECKSUM ERROR
= 3 ROM 2 CHECKSUM ERROR
= 4 ROM 3 CHECKSUM ERROR
= 5 READ PRINTER STATUS ERROR
= 6 READ PRINTER ROM ERROR
= 8 READ KEY STATUS ERROR
= 9 RAM REFRESH ERROR

After all the tests are run, the number of tests which failed is reported. The message "END TEST" follows.

DIAGNOSTIC 8 - CRT and Printer

What it does:

Starting in Graphics mode, the display memory is filled with ones then zeros. Then 128 ASCII characters and the ROM checksum are displayed in Alpha mode. Finally, a copy of the Alpha screen is printed.

How to run it:

To run the CRT and printer test, enter "DIAGNOSTIC 8, m" where m = number of repetitions, 1 to 32767.

Results:

Starting from the top row, the screen is white-out then blanked-out. The characters are displayed on the CRT and printed on the printer as in Figure 9-5. There is a beep after each test. After all the tests are run, the message "END TEST" is printed.

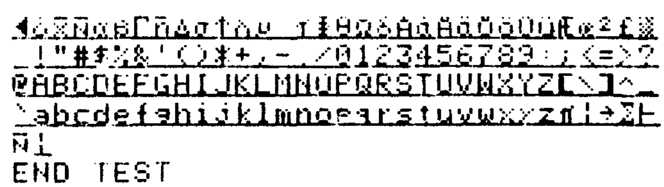


Figure 9-5. CRT/Printer Test Output

Intensity Mode

What it does:

The absolute light intensity on the diode is reported uncorrected for dark current and before calculating absorbance.

How to run it:

To enter the intensity mode such that subsequent "MEASURE" commands display the light intensity at the diode, enter "INTENSITY n,m" where

n = 0 INTENSITY AT EXISTING GAIN SETTING
= 1 INTENSITY AT GAIN, m = 0 TO 15
= 2 DARK CURRENT AT EXISTING GAIN SETTING
= 3 DARK CURRENT AT GAIN, m = 0 TO 15

To exit the intensity mode and reset photodiode amplifier gains, enter the command LAMP EXECUTE. To exit intensity mode and turn off the lamp, enter the command LAMP 0 EXECUTE.

Results:

To display intensity throughput versus wavelength:

```
INTENSITY 1,0  EXECUTE
LAMBDA  EXECUTE
ABSORBANCE EXECUTE
Y-SCALE 0 TO 17000  EXECUTE
MEASURE 1  EXECUTE
```

The spectrum should look similar to that in Figure 9-6.

The characteristics of the intensity spectrum are used to determine when a deuterium lamp should be replaced. As the lamp ages, the intensity output decreases by two different modes. A gradual loss of deuterium (outgassing, adsorption and chemical reactions) will preferentially degrade the low UV output of the lamp. The overall intensity of the lamp will decrease as anode materials are sputtered. If a deuterium lamp can be lit, the ultimate choice of when to replace the lamp depends on the analysis application.

In general, a lamp can still be used when the dark corrected intensity at 250 nm falls to one-half of the new lamp value. Typically, a new instrument with a new lamp will produce a dark corrected intensity of 1000 to 8000 counts at 250 nm. As the lamp ages and the optical surfaces become dirty, the intensity at the detector will gradually decrease. When the intensity at 250 nm falls to one-fourth of its original value, the overall spectrophotometer performance will be noticably reduced.

To measure the dark corrected intensity at 250 nm, clear the sample area, then enter the following commands:

```
ERASE STATUS  EXECUTE
ABSORBANCE 250  EXECUTE
INTENSITY 3,0  EXECUTE                  ! shutter closed, gain = 0
MEASURE  EXECUTE                        ! dark counts are printed
TO STANDARD 1  EXECUTE
INTENSITY 1,0    EXECUTE                ! shutter open, gain = 0
ABSORBANCE 250 - STANDARD 1  EXECUTE
MEASURE EXECUTE                         ! dark corrected counts are printed
ERASE STATUS EXECUTE                    ! return to default conditions
```

For those applications where intensity is critical, lamp intensity records should be maintained. For example, if the area of spectral interest is in the low UV (190-220 nm) the intensity in this region should be used to determine the guidelines for when the lamp should be replaced.

In addition to the use of the intensity mode for lamp intensity measurements, the user-callable diagnostic can be helpful for verifying proper spectrophotometer operation. The following tests can be used to check the operation of several parts of the optical system and detector electronics.

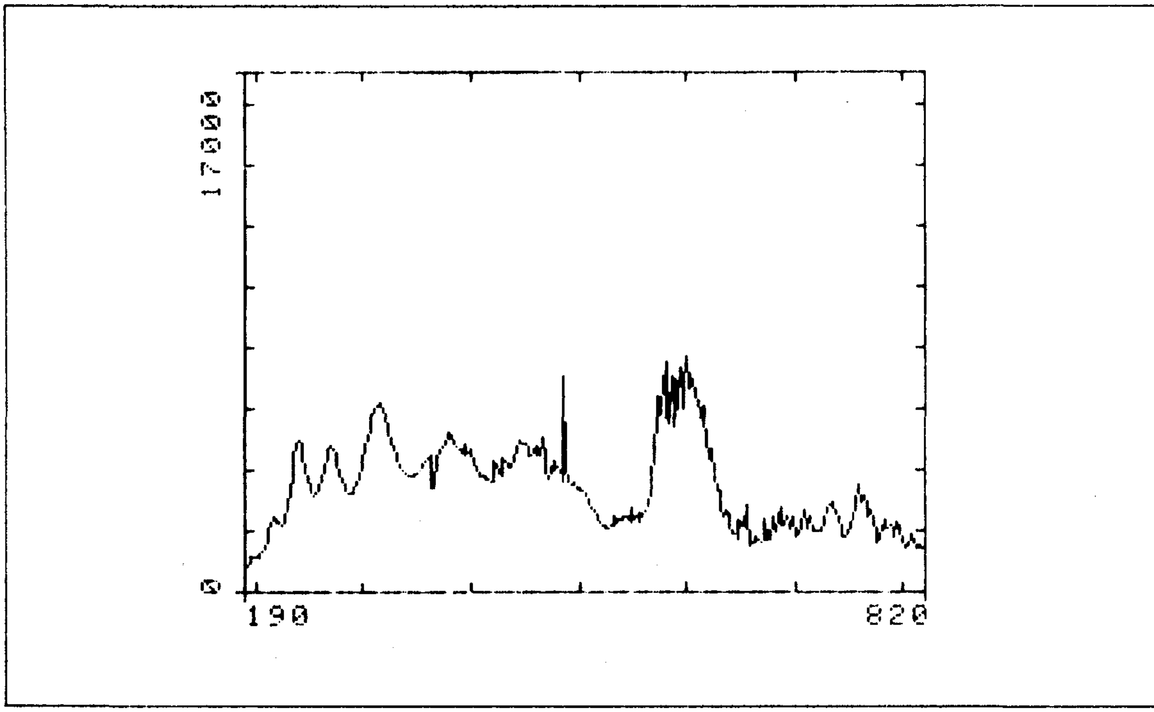


Figure 9-6. Lamp Intensity at Gain 0

Intensity Test

With the sample compartment clear, obtain a lamp intensity spectra by entering the commands:

ERASE STATUS EXECUTE
INTENSITY 1,0 EXECUTE
MEASURE EXECUTE
COPY

If the instrument is functioning properly, the intensity spectrum should be similar to that shown in Figure 9-6. Determine the value for the maximum intensity region of the spectra. All data points should be less than 16,128 counts. If the value at a given wavelength exceeds 16,128 counts, the intensity is beyond the normal range. For these regions of the spectrum, the HP 8451 will invalidate the data points in absorbance, transmittance, or derivative modes. This appears as a gap in an otherwise normal display.

The HP 8451 uses a 14-bit analog to digital converter for data conversion. Therefore, the maximum intensity value is 16,383 (i.e., 2^{14}-1) counts. Intensity values in the range 16,128 to 16,383 may indicate a failure in the lamp power supply, lamp, spectrograph or readout electronics. If the lamp is replaced and the problems remain, continue with the following tests.

Readout Electronics Noise Test

Enter the following commands:

ERASE STATUS EXECUTE
INTENSITY 3,15 EXECUTE
Y-SCALE 500 TO 2000 EXECUTE
LAMBDA 500 EXECUTE
MEASURE 0.1, 0.3, 0, 60 EXECUTE

after the one minute measurement is complete,

Y-SCALE EXECUTE
PLOTTER EXECUTE
COPY

If the instrument is operating properly, the difference between the maximum and minimum counts should be less than 25 counts. If this range is greater than 25 counts, service is required. Values outside this range may indicate excessive noise in the preamp or ADC circuitry. There could also be excessive noise in the power supplies.

Dark Offset Test

Clear the sample area, then enter the following commands:

ERASE STATUS EXECUTE
REFERENCE EXECUTE
INTENSITY 2 EXECUTE
MEASURE EXECUTE
COPY

For proper spectrophotometer operation, the average of all the data points should not exceed 2000 counts. If this value is exceeded, the preamp or ADC circuitry is likely to be defective. Individual data points can go as high as 5000 counts.

Lamp Drift Test

After a 15 to 20 minute lamp warm-up time has elapsed, clear the sample area, then enter the following commands:

ERASE STATUS EXECUTE
REFERENCE EXECUTE
INTENSITY 0 EXECUTE
Y-SCALE 10000 TO 16000 EXECUTE
LAMBDA 500 EXECUTE
MEASURE 0.1, 0.3, 0, 60 EXECUTE

after the one minute measurement is complete,

Y-SCALE EXECUTE
PLOTTER EXECUTE
COPY

This test measures the change in the lamp intensity over time. If the lamp output is stable, the difference between the maximum and minimum counts should be less than 30 counts. Values outside this range may indicate a faulty lamp or lamp power supply.

The results of these INTENSITY mode tests, should be used as a check of spectrophotometer performance. If the results of these tests are not within the given limits, the spectrophotometric performance could be diminished.

APPENDIX A

ERROR MESSAGES

The following is a summary of error messages that relate to the HP 8451, HP 85 and several enhancement ROMs (I/O, Mass Storage, Advanced Programming, Plotter/Printer, Matrix, Serial Interface, GPIO and HP-IB). Further information can be obtained from individual manuals.

Error Message	Meaning
1 UNDERFLOW	Expression underflows machine.
2 OVERFLOW	Overflow;
	Expression overflows machine.
	Attempt to store value>99999 or <-99999 in INTEGER variable.
	Attempt to store value >9.9999E99 or <-9.999E99 in SHORT variable.
3 COT/CSC = INF	COT or CSC of n*180°;n=integer.
4 TAN/SEC = INF	TAN or SEC of n*90°;n=odd integer.
5 0^NEG	Zero raised to negative power.
6 0^0	Zero raised to zero power.
7 NULL DATA	Null data:
	Uninitialized string variable, or missing string function assignment.
	Uninitialized numeric variable, or missing numeric function assignment.
8 /ZERO	Division by zero.
9 NEG^NON-INT	Negative value raised to non-integer power.
10 SQR(-)	Square root of negative number.

11 ARG OUT OF RANGE	Argument (parameter) out of range: ATN2(0,0). ASN or ACSN(-1<n<+1). ON expression GOTO/GOSUB; expression of range.
12 LOG(0)	Logarithm of zero.
13 LOG(-)	Logarithm of negative number.
15 SYSTEM	System error; correct by reloading program, pressing **RESET**, or turning system off, then on again.
16 CONTINUE BEFORE RUN	Continue before run; program not allocated.
17 FOR NESTING	FOR nesting too deep; more than 255 active **FOR-NEXT** loops.
18 GOSUB NESTING	GOSUB nesting too deep; more than 255 nested subroutines.
19 MEM OVF	MEMORY OVERFLOW - insufficient memory to perform operation. Attempting to store a standard that requires more than given memory; delete standards and program not required. Attempting to RUN a program that requires more than given memory. Attempting to edit too large a program. Delete a nonexisting line to deallocate program, then edit. Attempting to load a program larger than available memory. Attempting to open a file with no available buffer space. Attempting any operation that requires more memory than available. Attempting to load or run a large program after a ROM has been installed. ROMs use up a certain amount of memory. Refer to the appropriate ROM manual.

21 ROM MISSING	Attempting to RUN program that requires ROM. An attempt to edit program with missing ROM will usually SCRATCH memory.
22 SECURED	Attempt to edit, list, store, or overwrite a SECURE program.
23 SELF TEST	One of the self tests in the HP 85 portion of the instrument has failed. Turn the instrument off and check that the spectrophotometer software module is correctly installed. Turn the instrument back on again. If the error persists, service is required.
24	Too many (more than 14) ROMs.
25 TWO BIN PROGS	Two binary programs; attempting to load a second binary program into memory (only one binary program allowed in memory at any time).
30 OPTION BASE	OPTION BASE error: Duplicate OPTION BASE declaration. OPTION BASE after array declaration. OPTION BASE parameter not 0 or 1.
31 CHAIN	CHAIN error; CHAIN to a program other than BASIC main program: e.g., CHAINing to a binary program.
32 COM MISMATCH	COMmon variable mismatch.
33 DATA TYPE	DATA type mismatch: READ variable and DATA type do not agree. READ# found a string but required a number.
34 NO DATA	No DATA to read: READ and DATA expired. RESTORE executed with no DATA statement.

35 DIM EXIST VRBL	Dimensional existing variable; attempt to dimension a variable that has been previously declared or used. Move DIM statement to beginning of program and try again.
36 DIM Illegal	Illegal dimension: Illegal dimension in default array declaration. Array dimensions do not agree; e.g., referencing A(2) when A(5,5) is dimensioned or referencing A(0) when OPTION BASE 1 declared.
37 DUP FN	Duplicate user-defined function.
38 NO FN END	Function definition within function definition; needs FN END.
39 FN MISSING	Reference to a nonexistent user-defined function; Finding FN END with no matching DEF FN. Exiting a function that was not entered with a function call after branching to the middle of a multi-line function.
40 FN PARAM	Illegal function parameter; function parameter mismatch (e.g., declared as string, called as numeric).
41 FN=	FN=; user-defined function assignment. Function assignment does not occur between DEF FN and FN END.
42 RECURSIVE FN CALL	Recursive user-defined function.
43 NUMERIC INPUT	Numeric input wanted.
44 TOO FEW INPUTS	Less items were given than requested by an INPUT statement.
45 TOO MANY INPUTS	More items were given than requested by an INPUT statement.
46 NEXT MISSING	NEXT missing; FOR with no matching NEXT.
47 NO MATCHING FOR	FOR missing; NEXT with no matching FOR.
48 END	END statement necessary.

49 NULL DATA	No valid data in display and/or data buffer. Use STATUS STANDARD 0 to determine contents of data buffer. Uninitialized data.
50 BIN PROG MISG	Binary program missing; attempting to RUN program that requires binary program. An attempt to edit will usually SCRATCH memory.
51 RETURN W/O GOSUB	RETURN without GOSUB reference.
52 IMAGE	Illegal IMAGE format string; unrecognized character in IMAGE.
53 PRINT USING	Illegal PRINT USING: Data overflows IMAGE declaration. Numeric data with string IMAGE. String data with numeric IMAGE. PRINT USING image format string is not correct.
54 TAB	Illegal TAB argument. With DEFAULT ON, an illegal TAB argument gives a warning message and defaults to TAB(1).
55 SUBSCRIPT	String array error: Attempt to enter or retrieve an illegal string array element - that is, one with a zero or negative subscript or with a larger subscript than SMAX indicates. Attempt to use SLET, GET$, or SMAX on a nonexistent string array - that is, on a string variable that has not appeared in an SARRAY declaration.
56 STRING OVF	String array too small to accommodate an element assignment.
57 MISSING LINE	Missing line; reference to a nonexistent statement number.
60 WRITE PROTECT	Tape cartridge is write-protected; RECORD slide tab is in left-most position.
61 >42 FILES	Attempting to create/record more than 42 files on tape.

62 CARTRIDGE OUT	Cartridge out when attempting tape operations.
63 DUP NAME	Attempting to store to a standard, file, or extra memory which already exists.
64 EMPTY FILE	Attempting to access a standard, file, or extra memory which does not exist.
65 END OF TAPE	Tape run-off; check cartridge. Tape is full. Not enough space to CREATE data file.
66 FILE CLOSED	Attempting READ#/PRINT# to file that has not been opened with ASSIGN#. Attempting to close a closed file (warning only). Tape has been ejected and reinserted.
67 FILE NAME	Name does not exist or name not in quotes.
68 FILE TYPE	File type mismatch: Attempting to treat program file as data file, or vice versa. Attempting to treat binary program as BASIC program or vice versa. Attempting to treat data as binary program, or vice versa.
69 RANDOM OVF	Attempting to access beyond existing number of bytes in logical record, using random file access.
70 READ	System cannot read mass storage medium.
71 EOF	End-of-file.

72 RECORD	Record: Attempting to access a record that does not exist. Attempting to READ#/PRINT# at the end of file. Lost in record - close file to release the buffer.
73 SEARCH	HP 85: Bad tape cartridge, or tape not initialized.
74 STALL	Disc drive not found; make sure disc drive is on and press {STOP} or {RESET}.
75 NOT HP-85 FILE	Not an HP 85 file; cannot read.
80) EXPECTED	Right parantheses,), expected.
81 BAD EXPRESSION	Wrong kind or number of parameters or entries for command or BASIC statement.
82 STRING EXPR	String expression error; e.g., right quote missing or null string given for the name.
83 "," MISSING	Comma missing or more parameters expected (separated by commas).
84 EXCESS CHARS	Remove excess characters at end of good command, then press {EXECUTE}.
85 EXPR TOO BIG	Expression too big for system to interpret.
86 ILLEGAL AFTER THEN	Illegal statement after THEN.
87 BAD DIM	Bad DIM statement.
88 BAD STMT	Improper key entry or operation.

89 INVALID PARAM	Invalid parameter:
	ON KEY# less than 1 or greater than 8.
	Attempt to TRACE a calculator mode variable.
	PRINTER IS or CRT IS with invalid parameter.
	CREATE with invalid parameters.
	Assign#, PRINT#, or READ# with buffer number other than 1 through 10.
	Randam READ# to record 0.
	SETTIME with illegal time parameter.
	ON TIMER#, OFF TIMER# with number other than 1, 2, or 3.
	SCALE with invalid parameters.
	AUTO or REN with invalid parameters.
	LIST with invalid parameters.
	DELETE with invalid parameters.
	VAL$ with non-numeric parameter.
	Any statement, command, or function for which parameters are given but they are invalid.
90 LINE>9999	Line number too large; greater than 9999.
91 MISSING PARAM	Missing parameter; e.g., DELETE with missing or invalid parameters.
92 SYNTAX	Command or function not correct. Cursor returns to character where error found.
101 XFR	This is only a warning. It is issued when a program is paused with an I/O TRANSFER still active. Do not attempt to modify a program when a TRANSFER is active. Before you modify or rerun the program, stop all active transfers with a RESET, HALT, or ABORTIO instruction; or press the RESET key.

107 WARNING: TOO MANY PEAKS

More than 20 peaks were found. See PEAKFIND definition.

108 WARNING: OPTICAL SYSTEM

Internal diagnostic has found a problem. The alphabetic character that follows the message gives more information as to the cause of the problem. The character definitions are:

A - Excessive Dark Current

One or more of the diodes has a high background signal. Use intensity diagnostic to determine which diode(s).

B - Average Light Intensity Low

The sum of the signal from all diodes is low. Probable cause can be (1) light path may be blocked, (2) absorbance in light path, (3) shutter not opening. Check sample compartment and press {LAMP} {EXECUTE} to restart test.

C - Diode Gain Amplifier

The output of the analog amplifier is not responding properly according to the gain settings. The instrument will continue to operate but a service call is required to fix the problem.

D - Gain Leveling

The signal from one or more diodes is too high and cannot be adjusted to an acceptable level. Probable causes are: (1) high lamp output, (2) excessive dark current, (3) gain amplifier problem. Use intensity diagnostic to determine problem.

E - Net Intensity Low

The intensity after the dark current is subtracted is lower than an acceptable level for one or more diodes. Probable causes are: (1) absorber in light path, (2) low lamp intensity, (3) diode not responding. Check beam path or use intensity diagnostic to determine lamp intensity or diode response.

F - Analog to Digital Converter

Analog to digital converter or analog subtract circuitry not functioning. Turn the system OFF and ON again. If the error persists, a service call is required to correct the problem.

109 PRGM TYPE	Illegal subprogramming operation: Trying to RUN a subprogram. Trying to CALL a main program. Specifying a main program name in a FINDPROG command.
109 LAMP	Lamp cannot light. Trying to measure with lamp off. Lamp cover off.
109 COMMAND DURING MEASURE	A PLOTTER, PRINTER, or RECALL command is not allowed while a measure sequence is in progress.
109 # DIMS	Incorrect number of dimensions.
109 ILL MODE	A command has been executed in the wrong operating mode (e.g., ASSEMBLER has been typed when computer is already in assembler mode).
110 LBL	An invalid label has been seen; may have been either longer than six characters or beginning with a digit.
110 NO REFERENCE	A valid REFERENCE measurement does not exist for the MEASURE command.
110 NOT ENOUGH STDS	The number of standards is not correct for the specified concentration method. See Section 6 for proper number of standards.
110 ROM2	A checksum error has been detected in ROM#2 of the spectrophotometer firmware. Turn the instrument off and on again. If error repeats, replacement is necessary.
110 I/O CARD	An interface has failed self-test. This indicates a probable hardware problem.

110 NOT A 3-VECTOR	Vector specified does not have three elements.
110 IN USE	Redundant declaration: Declaring an existent string array variable to be a string array. Declaring an existent I/O ROM buffer variable to be a string array. Executing an ON KYBD statement after a binary program has taken control of the linkage to the keyboard.
111 RECURSIVE	Attempted recursive operation: A subprogram directly or indirectly tries to CALL itself. A subprogram directly or indirectly tries to SCRATCHSUB itself.
111 DIM MISMATCH	Incorrect number of elements.
111 I/O OPER	The I/O operation attempted is not valid with the type of interface being used. Some examples are: specifying a status or control register that does not exist, using a primary address with an RS-232 interface, or using an I/O statement that is not defined for the interface being used.
111 MEASURE INTERVAL	Measurement stopped prematurely, or time to process and output data exceeds measurement interval. Reduce data processing, lengthen interval, or try MODE 0.
111 NOT ENOUGH VALID DATA	Insufficient data for CONCENTRATION 4 calculations. See CONCENTRATION 4 definition.
111 OPCO	The opcode is not recognized; may have been because of misspelling, because there was no space between a label and the opcode, or because the opcode was entered in the first or second column after the line number.

112 ARP-DRP	Invalid ARP or DRP; ARPs and DRPs must be between 0 and 77 inclusive, and cannot be 1.
112 MEASURE PARAMETER	The MEASURE time parameters are not correct. See command definition.
112 CONC NOT POSSIBLE	Data or parameters incorrect. See CONCENTRATION or STATUS CONCENTRATION definition.
112 I/O ROM	The I/O ROM has failed the checksum self-test. This indicates a probable hardware problem. Try recycling the power (turn the computer off, then back on again).
112 P/P ROM	The Plotter/Printer ROM failed self-test.
112 AP ROM	The Advanced Programming ROM failed self-test.
112 M.S. ROM	The Mass Storage ROM failed self-test.
112 MATRIX ROM	The Matric ROM failed self-test.
113 OPER	Bad operand; e.g., LDM R34, = 3, remark. Because a number follows the equal sign in this example, the assembler expects another number after the comma. Also, each literal value must be specified with two digits if a BCD quantity.
113 MEASURE SYSTEM	Measurement processor has detected a hardware problem. The alphabetic character which precedes the error message gives more information as to the cause of the failure. The character meaning is as follows:

S - Multiplier

The hardware multiplier results are not correct. Turn system off and on again. If the error persists, then a service call is required to correct the problem.

T - Timer

The hardware timer circuitry is not working properly. Turn the HP 8451 off and on again. If the error message persists, then a service call is required to correct the problem.

U - Air Flow Sensor

The system has detected that the air flow to cool the interior of the HP 8451 is too low. The lamp is turned off to prevent overheating. Probable causes are: (1) obstruction of air path under the instrument, (2) fan not working. Check to see if the air filter is blocked and listen for fan noise. Turn on lamp after correcting the problem.

V - Interrupt

The system has detected an illegal interrupt. A service call is required to correct this problem.

113 INVALID SAMPLE DATA	The sample data, or the variance of the sample data, is invalid for the concentration calculation. Try a different wavelength range or measurement timing.
113	An interface-dependent error. HP-IB: The statement used requires the interface to be system controller. Serial: UART receiver overrun; data has been lost. BCD: Attempting to put the interface into an illegal mode. GPIO: An odd number of bytes was transferred when the interface was configured for 16-bit words.
113 DIM SIZE	Total number of elements specified when redimensioning exceeds the number originally dimensioned. Attempt to create empty array with OPTION BASE 0 in effect. Statement specifies result array created with OPTION BASE 0 in effect and empty operand array created with OPTION BASE 1 in effect.

113 PARAM MISMATCH	Parameter mismatch between a CALL statement and a SUB statement: Parameters disagree in type - as when a string variable is paired with a numeric variable. Parameters disagree in number - that is, the CALL parameter list is longer than the SUB parameter list.
114 CAN'T CALC FUNCTION	Cannot complete data processing due to improper data range or data type. Check STATUS and then change the function, display limits or the data type.
114 NO VARIANCE	The sample or standard data have no variance due to fast measurement. Without the variance, the maximum likelihood procedure cannot be used to calculate concentration. Use MODE 2 for least squares only procedure.
114	An interface-dependent error: HP-IB: The statement used requires the interface to be active controller. Serial: Receiver buffer overrun; data has been lost. BCD: Port 10 not currently available. GPIO: FHS TRANSFER aborted by STO.
114 NOT SQUARE	Array specified is not square. (The number of rows is not the same as the number of columns.)
114 FIN-LNK	Missing FIN or LNK statement. If the file name or file type is wrong in the LNK statement, then a "FILE NAME" or "FILE TYPE" error will be generated.
115 ASSM ROM	At power-on, the assembler ROM failed self-test. At a breakpoint, all errors generate this message.
115 NON-VECTOR	Array specified is not a vector.

115 ROM3	A checksum error has been detected in ROM #3 of the Advanced Techniques Module firmware. Turn instrument off and on again. If error repeats, replacement is necessary.
115	Output enable switch not set, or corresponding bit in Register B not set.
115	An interface-dependent error: HP-IB: The statement used requires the interface to be addressed to talk. Serial: Automatic disconnect forced. BCD: FHS TRANSFER aborted by FLGB. GPIO: Interface configuration does not allow an output enable or output operation on Port A or Port B.
116	An interface-dependent error: HP-IB: The statement used requires the interface to be addressed to listen. Serial: This error number not currently used. BCD: Data direction mismatch on current operation. GPIO: Cannot start operation because handshake CTL line is not in proper state.
116 STD MISSING	Standard(s) that are necessary for function or concentration calculations are not in memory. STATUS command will display the required standards and STATUS STANDARD will display the standards currently in memory.
117 SAMPLE AND STD DATA MISMATCH	Use STATUS STANDARD n command to check data types.

117	An interface-dependent error: HP-IB: The statement used requires the interface to be non-controller. Serial: This error number not currently used. BCD: Interface command has been directed to a non-existing field. GPIO: This error number not currently used.
118	An interface-dependent error: HP-IB: This error number not currently used. Serial: This error number not currently used. BCD: Cannot start operation because TL line is not in the proper state. GPIO: This error number not currently used.
118 DISPLAY LIMITS	There are no common data between the sample and the selected display limits. Use STATUS STANDARD 0 to check sample data limits. The current display limits can be checked by the STATUS command.
119 ROM1	A checksum error has been detected in ROM #1 of the spectrophotometer firmware. Turn the instrument off and on again. If the error repeats, replacement is necessary.
119	An interface-dependent error: HP-IB: This error number not currently used. Serial: This error number not currently used. BCD: Data format does not match the mode of the interface. GPIO: This error number not currently used.
120	An interface-dependent error. This error number not currently used.

129 MEDIUM	The storage medium is damaged.
130 NO TERM	A required terminator was not received from an interface or buffer during an ENTER statement. Remember that there is a default requirement for a line-feed statement terminator. Check your incoming character stream, ENTER list, and image specifiers.
130 DISC	Disc is not in drive or disc is not initialized.
131 TIME OUT	An input or an output command was initiated to an interface and could not complete. One probable cause is that the disc drive was turned off. Turn on disc drive and press {STOP}.

ROM IDENTIFICATION NUMBERS

Enhancement ROM	HP Part Number	ROM Number
Advanced Programming ROM	00085-15005	232
Assembler ROM	00085-15007	40
Input/Output ROM	00085-15003	192
Mass Storage ROM	00085-15001	208
Matrix ROM	00085-15004	176
Plotter/Printer ROM	00085-15002	240
Service ROM	00085-60952	224
Spectrophotometer Software Module	08451-60103	
(ROM 51H)		246
(ROM 51L)		062
Advanced Techniques Module	89050A	250

HP-IB MESSAGES

Mnemonic	Message Name	Responses
		Sngle Line Messages
ATN	Attention	The Controller Active places ATN true to source commands on the bus or in conjunction with EOI to do a parallel poll. When ATN is false, data may be sent over the bus by a designated talker.
IFC	Interface Clear (Abort)	The System Controller uses this to place talkers and listeners in an unaddressed state. If control has been passed, the System Controller again becomes Controller Active when it sends IFC.
REN	Remote Enable	Removes all devices from Local Lockout mode and causes all devices to revert to manual control.
SRQ	Service Request	Indicates a device's need for interaction with the controller.
EOI	End or identify	Terminates a flow of data, and can be used with ATN to do a parallel poll.
		Single Line Handshake Messages
DAV	Data Valid	Allows source to validate DIO lines.
NRFD	Not Ready For Data	Used to inform the source that all devices are ready for data.
NDAC	Not Data Accepted	Used by devices to inform the source that data has been accepted.
		Multi-Line Messages
GTL	Go To Local	Causes selected devices to switch to local (front or rear panel) control.
LAG	Listen Address Group	A group of 31 listen addresses, one of which corresponds to the listen address of the interface.

121	An interface-dependent error. This error number not currently used.
122	An interface-dependent error. This error number not currently used.
123 NO ";"	Syntax error. A semicolon delimiter was expected in the statement.
123 DISC ONLY	the command or statement is valid for disc only.
123 DIGITIZE	Digitizing process for DIGITIZE, LIMIT, LOCATE, or CLIP has been interrupted from the HP 85 keyboard and thus aborted. Attempting to digitize from the CRT.
124 ISC	Invalid select code in PLOTTER IS, PRINTER IS, or CRT IS. The error will not occur until you try to output to the non-existing interface card. The I/O card may not have identified itself at power on. Turn the HP 85 off, check all connections, then turn it on again.
124 FILES	The file directory on the storage medium is full.
125 VOLUME	The specified volume label was not found.
125 ADDR	Invalid address in PLOTTER IS, PRINTER IS, or CRT IS. (E.g., specifying PLOTTER IS 750. The largest HP-IB address is 31.)
126 PLOTTER	The addressed peripheral device does not respond. If the device does not respond within two seconds after it is addressed with a PLOTTER IS, PRINTER IS, or CRT IS statement, this error will occur.
126 MSUS	The specified mass storage unit specifier is invalid.

126 BUFFER	Four possible buffer problems: (1) The string variable specified has not been declared as an IOBUFFER, (2) Attempting to ENTER from a buffer which is out of data, (3) Attempting to OUTPUT to a buffer which is already full, (4) Attempting an output TRANSFER with an empty buffer. Be sure you have included the necessary IOBUFFER statement. Check the logical flow of your program (in what order are the statements executed). Buffer contents can be examined at any time by simply printing or displaying the string variable being used as the buffer. If this does not provide enough information, the buffer pointers can be examined with the STATUS statement.
127 NUMBER	An incoming character sequence does not constitute a valid number, or a number being output requires three exponent digits and an "e" format was specified. If the error is from an output operation, check the magnitude of the number and the format used. If the error is from an input operation, there are many possible causes. Here are some things to look for: more than 255 leading non-numeric characters, unexpected spaces in a character stream when a character-count format is used, punctuation sequences that include potentially numeric characters used in an order that is numerically meaningless.
127 READ VFY	A read verify error was encountered.
128 FULL	The command cannot be executed because the mass storage medium is full.
128 EARLY TERM	A buffer was emptied before all the ENTER fields were satisfied, or a field terminator was encountered before the specified character count was reached. Check your incoming character stream, ENTER list, and image specifiers.
129 VAR TYPE	The type (string or numeric) of a variable in an ENTER list doe snot match with the imate specified for that variable. Check your ENTER list and image specifiers.

Mnemonic	Message Name	Responses
UNL	Unlisten	Device becomes unaddressed to listen.
TAG	Talk Address Group	A group of 31 talk addresses.
UNT	Untalk	Causes a talker to become unaddressed to talk.
LLO	Local Lockout	Prevents local (front or rear panel) control of device functions.
DCL	Device Clear	Causes all devices to be initialized to a predefined or power-up state.
SDC	Selected Device Clear	Causes a device to be initialized to a predefined or power-up state.
SPD	Serial Poll Disable	Devices exit serial poll mode and are not allowed to send their status byte.
SPE	Serial Poll Enable	Devices enter serial poll mode and are allowed to send their status byte when addressed to talk.
GET	Group Execute Trigger	Signals one or more devices to simultaneously initiate a set of device dependent actions.
TCT	Take Control	Passes bus controller responsibilities from the current controller to a device which can assume the bus supervisory roll.
SCG	Secondary Command Group	A group of 32 commands which are only recognized if they immediately follow a talk of listen address.

Mnemonic	Message Name	Responses
DAB	Data Byte	Transfers device dependent information between a talker and one or more listeners. This may be programming information or data.

Note: Pressing the Reset key will reset the interface and return keyboard control to the operator. If the HP 85 is System Controller, pressing the Reset key will output the IFC message and set REN true.

ASSEMBLY-TIME ERRORS

Error Message	Error Condition
ILL NAM	A NAM statement has already been executed, or an ABS ROM has been executed.
AIF UND	The specified conditional assembly flag has not yet been defined as set or cleared.
ILL ABS	An ABS or NAM statement has already been encountered.
JMP FROM	The jump from that line is out of range.
JMP TO	The jump to that line is out of range.
UND LAB	After assembly was completed, this label had not been defined either in the program or in the optional global file.
ILL GLO	The GLO statement occurs after a NAM statement, ABS statement, or another GLO statement.

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